ANNEX D

WATER QUALITY EVALUATION OF CUMULATIVE IMPACTS FROM PROPOSED ORION AND CMB PULP MILLS

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Executive Summary

The International Finance Corporation of the World Bank Group (IFC) is currently assessing the financing of two pulp mills, Orion and CMB, located in the same area on the Uruguay shore of the Uruguay River. To fulfill the requirements of its Environmental Assessment Policy (OP 4.01), IFC commissioned Pacific Consultants International (PCI) and Malcolm Pirnie, Inc. to undertake a Cumulative Impact Study (CIS) of these pulp mills and their respective wood sources

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To provide a more extensive assessment of the potential cumulative impacts on local water quality (i.e., study area), an enhanced water quality impact evaluation was performed for emissions from the Orion and CMB Mills. A comprehensive hydrodynamic and water quality model had already been developed in the vicinity of the two mill discharges by Professor Ismael Piedra Cueva of the Faculty of Engineers, Universidad de la República, Montevideo, Uruguay, Institute of Fluid Mechanics and Environmental Engineering in support of the Orion EIA. Since the previous modeling effort for water quality was limited to an analysis of conservative constituents that do not degrade in the environment, an enhanced model was developed to provide an analysis of non-conservative parameters such as Biochemical Oxygen Demand (BOD) and dissolved oxygen levels.

Malcolm Pirnie utilized the internationally recognized RMA2 hydrodynamic model and RMA 11 water quality model with model input files obtained from Professor Piedra Cueva. Based on a review of the model input parameters and assumptions, river bathymetry, flow data, water level data and the results of the calibration analyses, it was concluded that the RMA 2 and RMA11 models are appropriate models for use in this analysis and that the models appear to reasonably reflect hydrodynamic and water quality characteristics of the river in the vicinity of the two discharges.

The additional modeling effort focused on two alternative discharge scenarios as specified by the IFC. Alternative 1 consists of an analysis of discrete discharges of

wastewater effluent from the City of Fray Bentos (OSE), the Orion project and the CMB project. Alternative 2 consists of a discrete CMB discharge and joint treatment of the Fray Bentos and Orion wastewaters with discharge at the Orion site.

Similar to the previous modeling effort, an analysis for each alternative under a 6,000 m^3/sec average river flow and 500 m^3/sec low flow condition was performed. The 500 m^3/sec flow condition is considered to be the worst case steady state flow condition for determining the potential cumulative impacts from the two projects. In addition to the steady state conditions, of particular interest is a condition that can cause a short-term change in Uruguay River flow direction at the pulp mill sites from east to west to west to east. Accordingly, a dynamic flow analysis using January 2000 river flow and water level data was performed for both Alternatives 1 and 2 to determine the cumulative impacts of the discharges under this condition.

The principal findings and assessment of the cumulative impacts of the two projects are presented below.

- Under the 6,000 m^3/sec average flow conditions, the modeling effort showed little potential for impacts outside of the mixing zones for the two pulp mill discharges. The plumes do not merge under these conditions and do not appear to have the potential for cumulative impacts. With the exception of the bay area immediately downstream of the Orion discharge, any discharges from the mills should not be detectable using conventional analytical techniques based on dilution factors greater than 1,000.
- Modeling results showed that no amount greater than the 5.0 mg/l water quality criteria for BOD_5, and 5.0 mg/l criteria for dissolved oxygen would occur outside of the mixing zones as a result of the proposed pulp mill discharges.
- The simulation of the discharges for both Alternatives 1 and 2 at the 500 m^3/sec low flow and January 2000 dynamic flow conditions, show that the CNB and Orion plumes do merge and have the potential for cumulative impacts. Areas with dilution factors on the order of 100 to 200 can exist along much of the Uruguay River shoreline between the CMB discharge and Fray Bentos at the 500

m^3/sec low flow condition. Dilution factors along the Argentine shoreline are generally greater than 1,000 under the steady state flow condition, although they can be reduced to 500 and 1,000 during the January 2000 model runs representative of flow reversal conditions.

- Several water quality criteria are currently exceeded at times primarily as a result of untreated municipal wastewater discharges. These water quality issues can not be addressed without upgrading municipal wastewater treatment facilities along both sides of the Uruguay River. The pulp mill discharges are not expected to be sources of additional fecal coliform and ammonia-nitrogen discharges to the river. Of the remaining constituents, phosphorus which can contribute to eutrophication conditions in the river is the most significant potential concern at the low flow condition. The elimination of the Fray Bentos discharge under Alternative 2, would reduce the net increase in phosphorus load from the two mills versus current conditions by approximately 1/3 and help to mitigate any additional impact from the pulp mills
- The modeling work and sensitivity analyses have identified a potential slow-flowing circulation pattern in the bay areas along the Uruguay shoreline including an area immediately downstream of the proposed Orion plant site in a bay adjacent to mouth of the Yaguarete River. While no amount exceeding the water quality criteria in this area was indicated by the modeling, this area is still of potential concern, particularly in view of elevated background nutrient levels in the river.

Recommendation for mitigation measures and additional assessments include:

- **Combined Fray Bentos/Orion Treatment –** While the modeling results do not show a significant difference in the results for Alternatives 1 and 2, combined treatment of the Fray Bentos and Orion discharges could be considered. A properly designed combined wastewater treatment facility will decrease the cumulative impacts from the two mills by reducing the net increase in loading of phosphorus, nitrogen and fecal coliforms to the river.

- **Provision for Future Tertiary Treatment** - Tertiary effluent treatment to provide supplemental removal has not been proposed for either project, but is normally implemented when the assimilative capacity of the receiving water is small and/or additional removal of target constituents is necessary to achieve site-specific water quality criteria. The need for tertiary treatment has not been requested by DINAMA, but this may change in the future. Therefore, it is recommended that the wastewater treatment facilities design for both pulp mills include the provision for a tertiary treatment upgrade to meet potential future DINAMA or IFC requirements, or if monitoring shows additional treatment would be needed to meet current or future water quality standards.
- **Orion Effluent Diffuser Design Optimization** – The preliminary design for the Orion discharge diffuser is located at a depth of approximately 8.25 meters of water along the Uruguay River shore and is not located in the deeper main river channel. While the modeling did not show any amount exceeding water quality criteria as result of the pulp mill discharges, sensitivity analyses indicate that water quality in a low-flow bay immediately downstream of the proposed Orion plant site is of potential concern and should be carefully monitored. The OSE raw water supply intake for Fray Bentos is located approximately 3 km downstream from the Orion site and located 70 m off shore across the mentioned small bay. As part of final design diffuser enhancements to extend it further into the main channel could provide enhanced dispersion of the effluent. The diffuser discharge location along with relocation of the OSE water supply intake are possible improvements affecting water quality. If the OSE intake were moved upstream of the Orion discharge, provisions for use of the existing intake under flow reversal conditions in the river should be maintained. Use of a near field dispersion models such as CORMIX or PLUME could be used in support of this evaluation. Alternatively, relocation of the diffuser to a location downstream of the small bay area, and the Fray Bentos potable water intake could also be considered. Feasibility studies with required effluent modeling would be needed to evaluate this alternative.

- **Future Discharge Mixing/Tracer/Modeling Studies –** Once the discharges are constructed and the pulp mills are in operation, discharge mixing and tracer studies should be performed to confirm effluent dispersion, mixing and dilution. The mixing and tracer studies should be performed under average flow, low flow and flow reversal conditions reviewed in this study. They should also be integrated with the collection of simultaneous water quality data for use in the development and calibration of an enhanced water quality model for the area. The enhanced model could be used to determine future wastewater treatment requirements and the potential impact of new discharges in the area of the projects.

1.0 INTRODUCTION

1.1 BACKGROUND

The International Finance Corporation of the World Bank Group (IFC) is currently assessing the financing of two pulp mills, Orion and CMB, located in the same area on the Uruguay shore of the Uruguay River. To fulfill the requirements of its Environmental Assessment Policy (OP 4.01), IFC commissioned Pacific Consultants International (PCI) and Malcolm Pirnie, Inc. to undertake a Cumulative Impact Study (CIS) of these pulp mills and their respective wood sources

As part of the CIS an independent water quality impact evaluation has been performed by Malcolm Pirnie, Inc. for two proposed pulp mills being considered for construction and operation in southwest Uruguay. The exact location of the two pulp mills is along the Rio Uruguay River just east of Fray Bentos, Uruguay. Figure 1-1 presents an aerial photograph of the Fray Bentos area (referred to as the "Study Area") that depicts the location of the two mills.

The Orion mill has been designed to produce 1,000,000 tons of air dried pulp on an annual basis, while the CMB Mill is anticipated to produce 500,000 tons of air dried pulp. Both mills will withdraw water form the Uruguay River for use in the Kraft pulp production process. Wastewater generated during production will be directed to on-site wastewater treatment facilities prior to discharge to the river. Both mills will be incorporating state of the art wastewater treatment technologies and equipment to minimize these emissions to meet international standards and Uruguay River water quality criteria. The estimated discharge characteristics were obtained from documentation developed in support of the Environmental Impact Assessment initially performed for each mill in support of approval from the Uruguay Environmental Ministry. Table 1-1 presents the projected discharge data along with relevant international standards.

Table 1-1

Parameter	Discharge to Wastewater Treatment		Proposed Effluent Quality		Relevant Standards		
	Orion	CMB	Orion	CMB	IFC Maximum	USEPA NSPS	IPPC
Flow (m^3/ton)	25	**30**	25	**30**	50 (target 20)	NA	30-50
DQO	55	45	15	12	15	NA	8-23
DBO_5	23	15	0,07	1,0	NA	2,41	0.3-1.5
AOX	0,3	1,4	0,15	0,2	0,2	0,272	>0.25
N	0,5	0,044	0,2	0,2	0,4	NA	0.1-0.25
P	0,075	0,032	0,02	0,02	0,05	NA	0.01-0.03
SS	10	9,0	1,0	1,0	NA	3,86	0.6-1.5
Temperature (°C)*	<37°	<36°	**	**	30°	NA	NA

All values in Kg/ADT except as noted
* CMB recently reported flows will be reduced to 30 m^3/ton. All other loading factors remain unchanged
** Less than 2°C temperature increase in receiving water to meet Decreto 253/79

The discharges to the Uruguay River will released from a diffuser structure in the channel river at each facility designed to maximize dispersion of the effluent. The diffuser characteristics based on preliminary design information received from the facilities are as follows:

- CMB – Approximately 138 meters in length with 63 diffuser outlets located in water 12 to 18 meters deep (CMB recently reported the diffuser lengths will be extended to a length of 200 meters with a total of 80 outlets).

- Orion - Approximately 200 meters in length with 80 diffuser outlets located water approximately 8.25 meters deep.

1.2 PREVIOUS MODELING EFFORTS

A water quality modeling effort and study of the pulp mill discharges has been performed by Professor Ismael Piedra Cueva of the Faculty of Engineers, Universidad de la República, Montevideo, Uruguay, Institute of Fluid Mechanics and Environmental

Engineering in the development of the report entitled PROYECTO ORION ESTUDIOS DE LA PLUMA DEL EMISARIO Y ESTUDIOS SEDIMENTOLOGICOS. This report was developed to support the Environmental Impact Assessment (EIA) performed for the Orion project. This modeling effort was very comprehensive and based on data collection and analysis that provided a basic understanding of the river system, the boundary conditions and included necessary information for model calibration and verification. These data included:

- Bathymetric and long-term hydrological and meteorological data for the section of the Uruguay River in the mills area.
- Long-term water quality stations along the river that record physical, chemical and biological parameters
- A sampling program that measured velocities near and downstream of the proposed plant site.

The modeling included development of both a far field hydrodynamic model to assess area wide impacts and a near field hydrodynamic model to evaluate conditions in the vicinity of ORION's discharge. A simulation of the combined effects of the CMB, ORION and OSE-Fray Bentos discharges was also performed. Simple dilution calculations for conservative constituents that do not degrade in the environment were performed based on the January 2000 dynamic flow condition and at the minimum monthly average river flow of 3100 m^3/sec and the low river flow of 500 m^3/sec for both the ORION discharge alone and with the CMB discharge.

A detailed description of the calibration and testing of the underlying model and the results is presented in Professor Piedra Cueva's report, which is included as Appendix A.

1.3 PURPOSE AND OBJECTIVES

To provide a more extensive assessment of the potential cumulative impacts on local water quality (i.e., study area), an enhanced water quality impact evaluation was performed for emissions from the Orion and CMB Mills. Since the previous modeling effort for water quality was limited to an analysis of conservative constituents that do not

degrade in the environment, an enhanced model was developed to provide an analysis of non-conservative parameters such as Biochemical Oxygen Demand (BOD). Based on the results of this additional modeling, an assessment of the cumulative impact of the mill discharges on Uruguay River dissolved oxygen concentrations and ability to comply with applicable water quality standards was performed. This report provides an overview of pertinent Uruguay River information, describes the additional modeling effort, summarizes the findings of the additional modeling effort, assesses potential mitigation measures and presents recommendations for future studies and monitoring.

1.4 PROJECT APPROACH

Since a comprehensive hydrodynamic and water quality model has already been developed in the vicinity of the two mill discharges, the existing model and input files were obtained from Professor Piedra Cueva. Using these files, the RMA11 water quality module was enhanced to provide for the analysis of non-conservative parameters such as BOD. The effort was implemented by:

- Verifying that the existing model, input parameters and input data/assumptions were reasonable and appropriate for the site-specific conditions.
- Developing appropriate model parameters such as BOD decay rate and SOD (sediment oxygen demand) to be used in the model.
- Preparation of new input files for the additional RMA11 model and additional alternatives.
- Interface the hydrodynamic (RMA2) and the enhanced RMA11 water quality model.
- Test RMA11 model response and sensitivity by varying key parameters
- Assess reasonableness of the RMA11 output results by comparison with available water quality data.
- Evaluate the cumulative effects of the Orion and CMB plants under normal steady annual average flow conditions (6,000 m^3/sec), low flow conditions (500 m3/sec) and one dynamic condition representative of flow reversal in the Uruguay River (January 2000) for two discharge alternatives: the base

scenario with the Orion, CMB and Fray Bentos municipal wastewater (OSE) discharges and joint treatment of the Fray Bentos municipal effluent at the Orion wastewater treatment plant.

- Compare model results with applicable Uruguay River water quality standards and permit conditions.

In addition to providing the model input files, Professor Piedra Cueva was also a technical resource in the development and review of the expanded water quality model. Malcolm Pirnie gratefully acknowledges his contribution and input.

2.0 URUGUAY RIVER OVERVIEW

2.1 RIVER SETTING AND CHARACTERISTICS

The Uruguay River and its tributaries in the vicinity of the sites of the two projects are described in great detail in Chapter 5, Section 5.2 of the ORION EIA, in Chapter 3, Section 1.6 of the CMB EIA. Significant studies of the river hydrodynamics and bathymetry have also been completed in the vicinity of the project sites. Major characteristics of the Uruguay River that influence water quality and the potential impacts of the effluent discharges from the two projects include:

- River Flows- The mean annual flow in the vicinity of Fray Bentos is 6,232 m^3/sec with a maximum monthly flow of 22,504 m^3/sec and a minimum monthly flow of 499 m^3/sec. The minimum weekly average flow for a 5 year return period is 519 m^3/sec, which CARU has indicated would be the flow most appropriate for determination of potential impacts of effluent loading on the River.
- Water Levels – River water levels are subject to significant variation with a maximum recorded daily variation at Fray Bentos of 6.65 meters. Water level variations are not directly related to river flow and are a result of a number of factors including Uruguay River flows, wind speed and direction, and the flows/water levels in other tributary rivers. Of particular interest is a condition that occurs as a result of low Uruguay River flows, high flows in the La Plata River and the effects of winds from the southwest. This combination of conditions can cause a short-term change in Uruguay River flow direction at the pulp mill sites from east to west to west to east.
- Channel Configuration – The Uruguay River provides good depth for navigation to the project sites with depths of 18 meters in the main navigation channel. Depths near the shores are much shallower and variable. The width of the river at the ORION site is approximately 1800 meters wide and approximately 800 meters wide to Isla Abrigo at the CMB site.

2.2 WATER QUALITY STANDARDS

The two primary standards have been established by CARU that affect water quality issues associated the effluent discharges from the two projects:

- Water Quality Standards – Water quality standards and numeric criteria have been established for 4 major categories of river uses. The use categories and numeric criteria for each are summarized in the Table 2-1 from Chapter 2 of the ORION EIA which is included in Appendix 2. The water use class applicable to these projects is Standard CARU Use Class 1 for water suitable for use for public drinking water supplies utilizing conventional water treatment processes.

- Effluent Discharge Criteria – CARU Decree 253/79 has also established effluent discharge limitations for a variety of pollutants. These effluent discharge limitations are presented in Table 2-2 from Chapter 2 of the ORION EIA, which is included in Appendix 3.

Each of the project's effluent discharge is also subject to permitting and approval by DINAMA, the environmental regulatory agency for Uruguay. In the project approvals, DINAMA has referenced Decree 253/79 as the effluent discharge limitations applicable to each project. Specific additional requirements for the ORION project have been established as follows:

Annual Average Discharge Limitations

- Adsorbable Organic Halides (AOX) – 6 mg/l
- Total Nitrogen (as N) – 8 mg/l
- Nitrates (as N) – 4 mg/l

2.3 EXISTING WATER QUALITY

In general, the quality of water in the Uruguay River is considered good but there are localized issues and exceedances of water quality criteria goals. In 1992, Estudio Nacional Ambiental (OPP-OEA-BID) concluded that the Uruguay is in good general

condition considering its large volume of flow and assimilative capacity. This conclusion was based on the studies and monitoring conducted by CARU with the support of other regulatory agencies. It did note that problems were detected in some areas including Bella Union, Salto, Concordia, Paysandu and the mouth of the Gualeguaychu River. This localized deterioration of water quality in was primarily attributed to runoff from areas of intense agricultural use and discharges from urban centers and industries with inadequate effluent treatment.

The quality of water in the Uruguay River has been the subject of numerous studies and water quality sampling events. From 1987 to date, CARU has conducted over 50 water quality monitoring events although only data from events over the periods from 1987 – 1990 and 2002 – 2003 have been published. Water quality sampling events in support of each of the two projects have been conducted. Water quality sampling for the CMB port facility is also routinely conducted.

Based on a review of the data contained in these documents, monitoring data for the vast majority of constituents shows compliance with applicable water quality standards. Parameters for which multiple exceedances of water quality criteria at monitoring locations in the vicinity of the two project sites are as follows:

- Fecal Coliforms
- Dissolved Oxygen
- Ammonia – Nitrogen
- Phosphorus
- Chromium
- Iron
- Zinc

Occasional low dissolved oxygen levels and exceedances of fecal coliform, ammonia-nitrogen and phosphorus concentration are believed to be related to the discharge of municipal wastewater effluents that receive inadequate treatment. Industrial effluent and runoff from agricultural uses may also contribute to the exceedances. Ammonia-nitrogen

can potentially cause toxicity in fish, but is not expected to be an issue at typical river pH levels. Phosphorus is a potential concern for eutrophication and increased aquatic plant growth in shallow, slow moving sections of the river. The source of chromium and zinc levels in the river is uncertain. Levels exceeding these criteria are potential a concern with regard of toxicity to aquatic species. Iron appears to be a naturally occurring compound in the river that exceeds the criteria primarily developed for drinking water supply aesthetic concerns.

2.4 SENSITIVE RECEPTORS

Water quality in the throughout Uruguay River in the vicinity of the proposed discharges is a potential concern with respect to compliance with applicable international water quality standards. Beyond a defined mixing zone in the immediate vicinity of the two discharges, Uruguay River water quality should not exceed the applicable standards included in Appendix B as a result of the discharges from the two mills. Sensitive receptors that could potentially be impacted by the discharges from the two pulp mills include:

- The Fray Bentos potable water discharge, which is located approximately 3 km downstream from the Orion project discharge.
- Beaches area located downstream of the discharges on both the Uruguay and Argentine coastlines.
- Slower moving sections of the Uruguay River in bays along the coastline where mixing and dilution are less than in the main river channel.

3.0 WATER QUALITY MODEL DESCRIPTION AND DEVELOPMENT

3.1 MODEL DESCRIPTION

To determine the potential for impact of these discharges on the Uruguay River, Malcolm Pirnie utilized internationally recognized hydrodynamic and water quality model to determine the potential concentrations for various pollutants in the river for comparison to applicable water quality standards. Our modeling efforts utilized the RMA2 hydrodynamic model and RMA 11 water quality model with model input files obtained from Professor Piedra Cueva as previously described. These RMA finite element models were originally developed with the support of the U.S. Army Corps of Engineers Waterways Experiment Station (WES) for simulation of hydrodynamics, water quality and sediment transport in rivers, bays, and estuaries. These models form the basis of the Corps of Engineers' TABS modeling system, which is used extensively by the U.S. Army Corps of Engineers and its consultants on projects throughout the United States.

3.1.1 RMA 2 HYDRODYNAMIC MODEL

The RMA2 model is a one and two dimensional hydrodynamic, depth averaged, free surface, finite element model. RMA2 can compute water surface elevations and flow velocities for subcritical flows at nodal points in a finite element mesh representing a body of water (such as a river, harbor, or estuary). RMA2 computes a finite element solution of the Reynolds form of the Navier-Stokes equations for turbulent flows. Friction is calculated with the Manning's or Chezy equation, and eddy viscosity coefficients are used to define turbulence characteristics. Both steady and unsteady state (dynamic) problems can be analyzed. Dynamic flow conditions caused by inflow hydrographs, tidal cycles, and storm effects can be accurately modeled.

3.1.2 RMA 11 WATER QUALITY MODEL

The RMA11 model is a finite element 3D contaminant transport model that can also be used for two dimensional analyses and uses the flows computed in RMA2. For contaminant modeling, a set of user-specified pollutant point loads are defined by mass or concentration values and by decay rates for each constituent. Any number of

contaminant point sources can be specified. The model will then compute the migration and dissipation of the constituents with time. Model capabilities for constituent modeling include:

- Temperature
- BOD
- Dissolved Oxygen
- The nitrogen cycle (including organic nitrogen, ammonia, nitrite and nitrates)
- The phosphorus cycle (including organic phosphorus and phosphates)
- Algal growth and decay
- Suspended sediment
- Conservative constituents

3.1.3 MODEL CALCULATION GRID

The model uses a finite element mesh for calculations associated with both the hydrodynamic and water quality modules. The development of the mesh is described in detail in Appendix A. The mesh provides coverage of the entire area in the vicinity of the discharges and allows for the assessment of potential impacts of the discharges throughout the mesh area. The mesh is more concentrated in the immediate area of the discharges and in the vicinity of sensitive receptors in close proximity to the discharges such as the Fray Bentos water supply intake. The mesh used in the model development is presented in Figure 3-1.

3.2 MODEL DEVELOPMENT AND VERIFICATION

3.2.1 RMA2 HYDRODYNAMIC MODEL

The development and calibration of the RMA2 hydrodynamic model using historic Uruguay River flow and water level data is described in great detail in Appendix A. Malcolm Pirnie has reviewed the model input parameters and assumptions, river bathymetry, flow data, water level data and the results of the calibration analyses performed to provide an independent assessment. Based on this review, it was concluded that the RMA 2 model is an appropriate model for use in this analysis and that the model

appears to reasonably reflect hydrodynamic characteristics of the river in the vicinity of the two discharges.

Malcolm Pirnie did make one modification to the underlying hydrodynamic model for the 500 m^3/sec flow condition. The average flow for the Gualeguaychu River of 210 m^3/sec was used for both the 6,000 m^3/sec and 500 m^3/sec Uruguay River flow in the previous modeling effort since low flow data for the Gualeguaychu River was not readily available. Under average conditions the Gualeguaychu River flow represents approximately 8.3% of the Uruguay River flow. A corresponding decrease in this 210 m^3/sec flow under the low flow scenario would be expected. Accordingly a Gualeguaychu River flow of 20 m^3/sec under the 500 m^3/sec low Uruguay River flow condition was used. Minor modifications were also made in the load correction factor used in the transition from near-field to far-field model to provide a more conservative analysis.

3.2.2 RMA11 WATER QUALITY MODEL

The development and calibration of the RMA11 water quality model using for conservative constituent presented in Appendix A. Malcolm Pirnie has reviewed the model input parameters and assumptions to provide an independent assessment. Based this review, it was concluded that the RMA 11 model for conservative constituents is an appropriate model for use in this analysis and that the model appears to reasonably reflect water quality characteristics of the river in the vicinity of the two discharges.

A description of the development and verification of the additional RMA11 water quality module for non-conservative constituents is as follows:

- **Model Setup –**In addition to the capability to calculate the impacts of BOD on dissolved oxygen concentrations, the RMA11 model also has the capability to calculate the effects of the nitrogen cycle, the phosphorus cycle, algal growth and suspended solids on dissolved oxygen concentration. Modeling of the phosphorus cycle, algal growth and suspended solids is extremely complex and are typically

only done for slower moving water bodies that exhibit characteristics of eutrophication. This modeling is also most beneficial following a site and discharge specific modeling and calibration program. A review of the EIAs and current river water quality data do not indicate that eutrophication is a current concern. Accordingly, the model incorporated the analysis of BOD and nitrogen cycle impacts on dissolved oxygen.

- **Boundary Conditions –** Input for the boundary conditions for the water quality was based upon available water quality data for the Uruguay River presented in the Orion and CMB projects EIAs. Based on these data, background Uruguay River concentrations of 4.0 mg/l of BOD_5 and 0.15 mg/l of ammonia-nitrogen were used. Dissolved oxygen data in the vicinity of the CMB discharge, which is the most upstream discharge location, consistently show concentrations in excess of 9.0 mg/l. Consequently a 9.0 mg/l was used for the upstream dissolved oxygen concentration and as the concentration in all tributary streams.

- **Oxygen Demand Approach –** BOD_5 is typically used by regulatory agencies as parameter for compliance with a discharge permit and for establishing water quality criteria. For discharges to water bodies with slow travel times such as lakes or reservoirs or under tidal conditions where flows can reverse or stagnate (such as the January 2000 condition), effluents can be expected to exert oxygen demand for a period greater than 5 days. For pulp and paper mill effluent modeling studies in the United States, the total BOD is determined by the ultimate oxygen demand (UOD) test, which represents the total biochemical oxygen demand after 60 days (or longer if necessary). This expression of BOD is typically used in modeling efforts to determine the impact of discharges on receiving water dissolved oxygen levels. Based on a review of data for pulp and paper mill water quality modeling, a BOD_5 to UOD ratio for pulp mill effluents of 2 to 5 is typically found with a median value on the order of 3.5. The associated oxidation or decay rate for in these modeling efforts was on the order of 0.04/day at 20 degrees C. In the absence of UOD data for these mills, a BOD_5 to UOD

ratio of 3.5 and a decay rate of 0.04/day were used to determine the impacts on Uruguay River dissolved oxygen levels.

- **Model Verification/Sediment Oxygen Demand (SOD) and Reaeration Rates –** Following construction of the additional water quality module, verification and sensitivity analyses were performed to determine if the model results reflected available water quality data. This was accomplished by adjusting model sediment oxygen demand (SOD) and reaeration rates until the model output reflected typical Uruguay River water quality data under existing conditions without the pump mill discharges. Available water quality data presented in the Orion and CMB EIAs show typical BOD_5 concentrations in the vicinity of Fray Bentos of 4.0 mg/l and typical dissolved oxygen concentrations of 7.0 mg/l to 8.0 mg/l. This represents a decrease in the typical dissolved oxygen concentration of 9.0 mg/l or greater found in the vicinity of the proposed CMB discharge. Based on these sensitivity analyses performed, a SOD of 500 mg/m2/day and the RMA 11 model Option 0 for the Churchill reaeration formula were found to best represent existing conditions. A model run showing dissolved oxygen concentrations at the 6,000 m^3/sec is presented as Figure 3-2. As shown, Uruguay River dissolved oxygen concentrations in the vicinity of Fray Bentos are generally on the order of 6.0 to 8.0 mg/l, consistent with current conditions. Two slight anomalies with dissolved oxygen conditions less than 5.0 mg/l are shown, one in the bay area downstream of the proposed Orion discharge, and another along the Argentine coast upstream of Isla Abrigo. It should be noted that these anomalies are not consistent with available water quality monitoring data and appear to be a result of localized dissolved oxygen fluctuations in the model. These fluctuations are likely a result of a combination of factors including limited bathymetric survey data that could introduce localized anomalies around selected contour definitions. However, we believe the overall results of the model are unaffected by these localized fluctuations.

4.0 CUMULATIVE IMPACT ASSESSMENT ALTERNATIVES AND INPUT PARAMETERS

4.1 DISCHARGE ALTERNATIVES

The additional modeling effort focused on two alternative discharge scenarios as specified by the IFC. A description of the alternatives and summary of the model input parameters for each are presented in the following sections.

4.1.1 ALTERNATIVE 1 – DISCRETE DISCHARGES FROM FRAY BENTOS, ORION AND CMB

Alternative 1 consists of an analysis of discrete discharges of wastewater effluent from the City of Fray Bentos (OSE), the Orion project and the CMB project. This alternative represents the cumulative impact of the two additional discharges and was as previously modeled in the report entitled PROYECTO BOTNIA ESTUDIOS DE LA PLUMA DEL EMISARIO Y ESTUDIOS SEDIMENTOLOGICOS, which is included in Appendix A. The effluent discharge characteristics of the two mills used for input to the model are based on the projected effluent discharges (kg/ADT) presented in Table 1-1, respective production rates of 1,000,000 ADT/year and 500,000 ADT/year for the Orion and CMB discharges, and 350 production days per year. The detailed information on the characteristics of the municipal wastewater discharge from Fray Bentos (OSE) was not readily available. This discharge reportedly receives low levels of treatment, so the characteristics of a municipal wastewater without treatment were assumed to be conservative for this low flow.

The effluent characteristics used for Alternative 1 are summarized in Table 4-1. CMB recently reported, after completion of the modeling effort, that its flows would be reduced from 40 kg/ADT to 30 kg/ADT even though all other discharge rates remained the same. As a result, the mass loads of pollutants to the river from CMB would remain unchanged and the results of modeling would not be significantly affected by the change in discharge flow for either Alternative 1 or 2.

Table 4-1
Alternative 1 Effluent Discharge Characteristics
(mg/l except as noted)

Parameter	OSE	ORION	CMB
Flow (m^3/sec)	**0.042**	**0.83**	**0.52**
BOD_5	**300**	**28**	**25**
UOD	**450**	**98**	**87.5**
N	**48**	**8**	**5**
P	**8**	**0.8**	**0.5**
TSS	**300**	**40**	**25**
AOX	**0.021**	**6**	**5**

4.1.2 ALTERNATIVE 2 – DISCRETE CMB DISCHARGE AND COMBINED FRAY BENTOS/ORION DISCHARGE

The Orion project EIA discussed the possibility of joint treatment of the Fray Bentos municipal wastewater at the Orion wastewater treatment facility. While construction of a wastewater pump station and force main from Fray Bentos to the Orion site would be required, a joint treatment facility for Fray Bentos and the Orion project does offer the following potential benefits:

- An upgrade in effluent treatment capability of the current Fray Bentos discharge that would reduce its current nitrogen, phosphorus and organic loadings to the Uruguay River, and would also potentially result in improved water quality in downstream areas such as Las Canas.
- With the provision for disinfection of the Fray Bentos wastewater prior to entering the pulp mill treatment system, a reduction in fecal coliform discharges to the river would result.
- Uruguay River water quality concerns currently include ammonia-nitrogen and phosphorus, which are primarily suspected to be a result of the current low levels

of municipal wastewater treatment. These compounds may need to be added to the ORION wastewater to provide adequate nutrient levels for biological treatment. Treatment of the Fray Bentos wastewater at the ORION facility could potentially eliminate the need for addition of these nutrients and also result in a reduction of the overall level of discharge of these constituents to the river.

The effluent discharge characteristics for Alternative 2 are presented in Table 4-2. With joint treatment, the revised flow from the Orion project is 0.87 m^3/sec. Based on the relatively small volume of the Fray Bentos flow compared to the Orion project flow, the available treatment capacity of the Orion wastewater treatment system and the expected consumption of the Fray Bentos nitrogen and phosphorus in the treatment system, the remaining Orion project effluent characteristics will not be significantly affected.

Table 4-2
Alternative 2 Effluent Discharge Characteristics
(mg/l except as noted)

Parameter	OSE	ORION	CMB
Flow (m3/sec)	**0**	**0.87**	**0.52**
BOD_5	**0**	**28**	**25**
UOD	**0**	**98**	**87.5**
N	**0**	**8**	**5**
P	**0**	**0.8**	**0.5**
TSS	**0**	**40**	**25**
AOX	**0**	**6**	**5**

4.2 STEADY STATE FLOW ANALYSIS

A steady state flow analysis was performed to determine the potential cumulative impacts of the discharges under both average and low flow river conditions. The mean annual flow in the vicinity of Fray Bentos is 6,232 m^3/sec, the maximum monthly flow is 22,504

m^3/sec and the minimum monthly flow is 499 m^3/sec. The minimum weekly average flow for a 5 year return period is 519 m^3/sec, which CARU has indicated would be the most appropriate flow for determination of potential impacts of effluent loading on the River. Similar to the previous modeling effort detailed in Appendix A, an analysis for each alternative under a 6,000 m^3/sec average river flow and 500 m^3/sec low flow condition was performed. The 500 m^3/sec flow condition is considered to be the worst case steady state flow condition for determining the potential cumulative impacts from the two projects.

4.3 DYNAMIC FLOW ANALYSIS

In addition to the steady state conditions, of particular interest is a condition that occurs as a result of low Uruguay River flows, high flows in the La Plata River and the effects of winds from the southeast. This combination of conditions can cause a short-term change in Uruguay River flow direction at the pulp mill sites from east to west to west to east. This condition can potentially impact mixing and dilution of the discharge result in a different area of impact than that associated with the steady state flow condition.

As part of the previous modeling effort detailed in Appendix A, a simulation of the combined effects of the CMB, ORION and OSE-Fray Bentos discharges was performed using January 2000 river data when these conditions occurred. The actual river flows during this period averaged 727 m^3/sec. Accordingly, a dynamic flow analysis using January 2000 river flow and water level data was performed for both Alternative 1 and 2 to determine the cumulative impacts of the discharges under this condition.

4.4 MODEL OUTPUT PRESENTATION

Based on our review of the previous modeling efforts, available water quality data and applicable water quality criteria, the following approach to model output and presentation was developed to assess the cumulative impact of the pulp mill discharges:

- **Conservative Parameters –** Similar to previous modeling efforts, model simulations were made with a 30 mg/l discharge of a conservative tracer

substance with a background river concentration of 0.0 mg/l. This scenario represents the basic configuration and extent of the discharges in the Uruguay River. It is also an effective means to show the cumulative impacts of the discharges from the two mills. Based on a review of available water quality data and projected mill effluent characteristics, figures were developed to illustrate the maximum possible extent of the plume that could be analytically detected in water quality sampling following dilution. A dilution ratio of 1000:1 was selected based on a projected Orion mill AOX discharge of 6.0 mg/l, a river background concentration of 0.0 mg/l and a minimum AOX analytical quantification limit of 0.006 mg/l. Model results figures were developed that show the concentration of the conservative tracer substance. The dilution ratio associated with the tracer concentrations are as follows:

Tracer (mg/l)	Dilution Ratio
0.30	100
0.15	200
0.12	250
0.09	333
0.06	500
0.03	1,000

Figures showing AOX concentrations modeled as a conservative constituent were also prepared to present a worst case situation, even though some degradation of AOX in the environment will occur.

- **Non-conservative Parameters –** Model runs for non-conservative parameters that degrade in the environment were also performed to assess the impact of the discharges on Uruguay River dissolved oxygen levels and compliance with the 5.0 mg/l water quality criteria. Model output to determine compliance with the 5.0 mg/l water quality criteria for BOD_5 were also developed using a background Uruguay River concentration of 4.0 mg/l. These model runs were performed at the 6,000 m^3/sec and 500 m^3/sec steady state, and January 2000 dynamic flow conditions.

- **Presentation of Results -** Model runs and figures were developed at the 6,000 m^3/sec average flow, 500 m^3/sec low flow and January 2000 dynamic flows for the conservative parameters. Figures for the steady state flow conditions represent the maximum extent of the plume at those flows. Video simulations for the entire 30 day period for January 2000 were prepared. Report figures for the January 2000 dynamic flow scenario depict the potential upstream extent of the plumes and were taken from Day 30 of the simulation. Model runs for the non-conservative parameters were performed at the 500 m^3/sec steady state and January 2000 dynamic flow conditions to represent the worst case conditions under low flows. Tables indicating the potential dilution of the plumes at various sensitive locations along the Uruguay and Argentine coasts were also prepared. Figures 4-1 presents these locations at which dilution ratios were summarized.

5.0 WATER QUALITY MODEL RESULTS

5.1 ALTERNATIVE 1 – DISCRETE DISCHARGES FROM FRAY BENTOS, ORION AND CMB

Alternative 1 consists of discrete discharges from the Orion and CMB pulp mills, and the Fray Bentos municipal wastewater. Figures illustrating the proposed discharge are as follows:

- Figure 5-1 – Alternative 1: 6,000 m^3/sec Dilution Analysis
- Figure 5-2 – Alternative 1: 500 m^3/sec Dilution Analysis
- Figure 5-3 – Alternative 1: January 2000 Dilution Analysis
- Figure 5-4 – Alternative 1: 6,000 m^3/sec AOX Concentrations
- Figure 5-5 – Alternative 1: 500m^3/sec AOX Concentrations
- Figure 5-6– Alternative 1: January 2000 AOX Concentrations
- Figure 5-7 – Alternative 1: 6,000 m^3/sec BOD_5 Concentrations
- Figure 5-8 – Alternative 1: 500 m^3/sec BOD_5 Concentrations
- Figure 5-9 – Alternative 1: January 2000 BOD_5 Concentrations
- Figure 5-10 – Alternative 1: 6000 m^3/sec Dissolved Oxygen Concentrations
- Figure 5-11 – Alternative 1: 500 m^3/sec Dissolved Oxygen Concentrations
- Figure 5-12 – Alternative 1: January 2000 Dissolved Oxygen Concentrations

Available dilutions at the 6,000 m^3/sec discharge and 500 m^3/sec discharges for Alternative 1 at the location shown on Figure 4-1 are presented in Table 5-1.

Table 5-1
Dilution Analysis Summary
30 mg/l Conservative Tracer Discharge

Alternative 1

Flow (m3/s)	Receptor Location	Los Perros	Yaguarete	Ubici	OSE	Hornos	El Raviol	Fray Bentos	Las Cañas	Gualeg.	Isla Sauzal
6000	C (mg/l)	0.017	0.005	0.041	0.016	0.025	0.020	0.013	0.012	0.000	0.001
	Dilution	1,786	6,479	739	1,875	1,210	1,515	2,239	2,564	187,500	58,824
500	C (mg/l)	0.416	0.000	0.072	0.195	0.263	0.202	0.186	0.146	0.000	0.006
	Dilution	72	1,357,466	418	154	114	149	161	205	1,132,075	5,068

Alternative 2

Flow (m3/s)	Receptor Location	Los Perros	Yaguarete	Ubici	OSE	Hornos	El Raviol	Fray Bentos	Las Cañas	Gualeg.	Isla Sauzal
6000	C (mg/l)	0.017	0.005	0.042	0.017	0.026	0.019	0.013	0.011	0.000	0.001
	Dilution	1,734	6,276	709	1,807	1,163	1,587	2,400	2,679	184,049	58,594
500	C (mg/l)	0.434	0.000	0.075	0.202	0.273	0.191	0.172	0.127	0.000	0.006
	Dilution	69	1,304,348	401	149	110	157	174	236	1,102,941	5,051

Results of the modeling analysis for Alternative 1 for each constituent modeled are as follows:

- **Dilution Analysis –** As illustrated in Figure 5-1 under the 6,000 m^3/sec average flow, dilution factors at the CMB discharge exceed 1,000 very quickly resulting is dissipation of the plume upstream of the Orion discharge. This indicates that the proposed pulp mills would not exhibit a cumulative impact under average flow conditions. With the exception of the bay area across from the Orion discharge, dilution factors exceed 1,000 throughout the remainder of the river area including along the beaches downstream of Fray Bentos and the Argentine shoreline. Dilution factors in the bay area across from the Orion discharge are generally between 500 and 1,000. Under the 500 m^3/sec low flow condition shown in Figure 5-2, dilution factors along the Argentine shoreline generally exceed 1,000 and are between 300 and 500 along the Uruguay shoreline between the CMB and Orion discharges. Since the dilution factors associated with the CMB plume do not decrease below 1,000 before it reaches the Orion discharge, the plumes do merge and some potential for cumulative impacts do exist. Dilutions factors on the order of 75 - 100 exist over portion of the bay across from the Orion discharge and between 100 and 250 downstream of Fray Bentos. Under the January 2000 flow condition shown in Figure 5-3, the area of potential impact of the plumes merge and can migrate upstream during these conditions. The areas where dilution factors on the order of 500 to 1,000 are present along the Argentine shoreline on Isla Sauzal and can extend upstream of and on both sides of Isla Abrigo across from the CMB discharge. Dilutions on the order of 200 to 300 exist along much of the Uruguay shoreline between Fray Bentos and the CMB discharge. It does not appear that areas with dilution factors of less than 150 exist any where beyond the immediate vicinity of the discharges.

- **AOX Concentrations –** AOX, which does not have a water quality standard, has been modeled as a conservative constituent and show the dispersion patterns as

presented in the dilution analysis above. Under the 6,000 m^3/sec average flow condition shown in Figure 5-4, AOX concentrations are below the 0.006 mg/l analytical quantification limit for all areas except the bay area across from the Orion discharge. Under lower flow condition shown in Figure 5-5, AOX concentration do not generally exceed 0.006 mg/l along the Argentine shoreline. Concentrations on the order of 0.024 mg/l 0.06 mg/l exist over portion of the bay across from the Orion discharge and downstream of Fray Bentos. Lower concentrations on the order of 0.006 mg/l to 0.024 mg/l occur along the Uruguay shoreline between the CMB and Botnia discharge. Under the January 2000 flow condition shown in Figure 5-6, the area of potential impact of the plumes merge and can migrate upstream during these conditions. The areas of AOX concentrations 0.006 mg/l and 0.012 mg/l are present along the Argentine shoreline on Isla Sauzal and can extend upstream of and on both sides of Isla Abrigo across from the CMB discharge. AOX concentrations on the order of 0.018 mg/l to 0.03 mg/l exist along much of the Uruguay shoreline between Fray Bentos and the CMB discharge. It does not appear that areas with AOX concentrations exist above 0.042 mg/l any where beyond the immediate vicinity of the discharges.

- **BOD_5 –** BOD_5 modeling results for BOD_5 shown in Figure 5-7 at the 6,000 m^3/sec show no exceedances of the BOD_5 criteria as a result of the pulp mill discharges. Two small areas in the bay area immediately downstream of the Orion mill show some minor exceedances, but these were also shown in the existing condition model and are not consistent with available water quality data. Modeling results of BOD_5 concentrations show in Figures 5-8 and 5-9 for the 500 m^3/sec and January 2000 dynamic flow conditions do not show any exceedances of the 5.0 mg/l water quality limit for BOD_5 as a result of the pulp mill discharges. A very small area along the Argentine shoreline opposite Isla Abrigo is shown to exceed 5.0 mg/l but this area was also present in the sensitivity analysis runs for existing conditions without the pulp mill discharges. The highest BOD_5 concentrations of between 4.0 and 5.0 mg/l shown are in the

vicinity of the discharges of the Yaguarete and Gualeguaychu Rivers, which are associated with the assumed background BOD_5 concentration in these rivers rather than the pulp mill discharges.

- **Dissolved Oxygen –** As with the BOD_5 discharges**,** modeling results for dissolved oxygen concentrations show in Figures 5-11 and 5-12 for the 500 m^3/sec and January 2000 dynamic flow conditions do not show any exceedances of the 5.0 mg/l water quality limit for dissolved oxygen. The dissolved oxygen concentrations generally are between 6.0 to 8.0 mg/l throughout the study area and are generally above 7.0 mg/l along both shorelines. A very small area along the Argentine shoreline upstream of Isla Abrigo is shown but this area was also present in the sensitivity analysis runs for existing conditions without the pulp mill discharges. As with the BOD_5 results for the 6,000 m^3/sec conditions, two small areas in the bay area immediately downstream of the Orion discharge show slightly depressed dissolved oxygen levels in Figure 5-10. The anomalies are also present in the existing conditions model shown in Figure 4-2, are not consistent with available water quality data and are not a result of the pulp mill discharges.

5.2 ALTERNATIVE 2 – DISCRETE CMB DISCHARGE AND COMBINED FRAY BENTOS/BOTNIA DISCHARGE

Alternative 2 consists of a discrete discharge from the CMB pulp mill and a combined Fray Bentos and Orion discharge from the Orion pulp mill site. Figures illustrating Alternative 2 are as follows:

- Figure 5-13 – Alternative 2: 6,000 m^3/sec Dilution Analysis
- Figure 5-14 – Alternative 2: 500 m^3/sec Dilution Analysis
- Figure 5-15 – Alternative 2: January 2000 Dilution Analysis
- Figure 5-16 – Alternative 2: 6,000 m^3/sec AOX Concentrations
- Figure 5-17 – Alternative 2: 500m^3/sec AOX Concentrations
- Figure 5-18 – Alternative 2: January 2000 AOX Concentration
- Figure 5-19 – Alternative 2: 6,000 m^3/sec BOD_5 Concentrations

- Figure 5-20 – Alternative 2: 500 m^3/sec BOD_5 Concentrations
- Figure 5-21 – Alternative 2: January 2000 BOD_5 Concentrations
- Figure 5-22 – Alternative 2: 6,000 m^3/sec Dissolved Oxygen Concentrations
- Figure 5-23 – Alternative 2: 500 m^3/sec Dissolved Oxygen Concentrations
- Figure 5-24 – Alternative 2: January 2000 Dissolved Oxygen Concentrations

Available dilutions at the 6,000 m^3/sec discharge and 500 m^3/sec discharges for Alternative 2 at the locations shown on Figure 4-1 are also presented in Table 5-1.

Results of the modeling analysis for Alternative 2 for the constituents discussed under Alternative 1 are very similar in plume geometry, extent and concentrations based on results presented in Figures 5-13 through 5-24. No exceedances of water quality standards were found for Alternative 2 as a result of the pulp mill discharges. Based on a comparison of Alternative 1 and 2 dilution ratios presented in Table 5-1, dilution ratios were found to be slightly greater (i.e. lower concentrations of discharge constituents) along the Uruguay shoreline to the south of Fray Bentos for Alternative 2 as a result of the elimination of the Fray Bentos discharge. Very slight decreases in dilutions ratios (i.e. higher concentrations of discharge constituents) were found for Alternative 2 in the bay area immediately downstream of the Orion discharge as a result of the slightly higher Alternative 2 Orion flows. These variations in dilution ratios for Alternatives 1 and 2 are very small and not expected to be significant or readily detectable in water quality monitoring.

6.0 ASSESSMENT OF CUMULATIVE IMPACTS

6.1 POTENTIAL WATER QUALITY IMPACTS

6.1.1 COMPLIANCE WITH WATER QUALITY CRITERIA

The principal findings and assessment of the cumulative impacts of the two projects are presented below. This evaluation has primarily focused on the low river flow conditions (500 m^3/sec flows and January 2000 flow reversal conditions), which are the worst case condition and used by regulatory agencies to assess potential water quality impacts. The available river flows under average conditions of approximately 6,000 m^3/sec, will provide much greater dilution and minimize the potential for cumulative impacts under typical conditions.

- Modeling results showed that no amount greater than the 5.0 mg/l water quality criteria for BOD_5 and 5.0 mg/l criteria for dissolved oxygen would occur outside of the mixing zones as a result of the proposed pulp mill discharges.
- The simulation of the discharges for both Alternatives 1 and 2 at the 500 m^3/sec low flow and January 2000 dynamic flow conditions, show that the CMB and Orion plumes do merge and have the potential for cumulative impacts. Area with dilution factors on the order of 100 to 200 can exist along much of the Uruguay shoreline between the CMB discharge and Fray Bentos at the 500 m^3/sec low flow condition. Dilution factors along the Argentine shoreline are generally greater than 1,000 under the steady state flow condition, although can be reduced to between 500 and 1,000 during the January 2000 model runs representative of flow reversal conditions.
- The parameters for which current water quality criteria can currently be exceeded at times are listed in Section 2.3. These exceedances are reported to be primarily a result of untreated municipal wastewater discharges. These water quality issues can not be addressed without upgrading municipal wastewater treatment facilities along both sides of the Uruguay River. The pulp mill discharges are not expected to be sources of additional fecal coliform and ammonia-nitrogen discharges to the river. Of the remaining constituents, phosphorus which can contribute to

eutrophication conditions in the river is the most significant concern. The two pulp mills will contribute an additional 0.3% load of phosphorus to the river under average flow conditions, which is not expected to be significant. At low flow conditions, an increased phosphorus load of approximately 3.5% would occur from the pulp mill discharges under Alternative 1. The elimination of the Fray Bentos, discharge under Alternative 2 would reduce the net increase in phosphorus load from the two mills versus current conditions by approximately 1/3 and help mitigate any additional impact from the pulp mills.

6.1.2 POTENTIAL FOR IMPACTS ON SENSITIVE RECEPTORS

Under average flow conditions, the modeling effort showed little potential for impacts outside of the mixing zones for the two pulp mill discharges. With the exception of the bay area immediately downstream of the Orion discharge, any discharges from the mills should not be detectable using conventional analytical techniques based on dilution factors greater than 1,000.

The modeling work and sensitivity analyses have identified a potential slow-flowing circulation pattern in the bay areas along the Uruguay shoreline including an area immediately downstream of the proposed Orion plant site in a bay area off the mouth of the Yaguarete River. The previous modeling study presented in Appendix A also simulated the sediment transport and deposition pattern using the SED2D model and demonstrated the nature of a potential sediment trap in this area. While no amounts exceeding water quality criteria in this area was indicated by the modeling, this area is still a potential concern, particularly in view of elevated background nutrient levels in the river. Accordingly, recommendations for mitigation measures and additional assessment are presented in the following sections.

6.2 MITIGATION MEASURES

Based on our evaluation we recommend that the following mitigation measures be considered:

- **Combined Fray Bentos/Orion Treatment –** While the modeling results do not show a significance difference in the results for Alternatives 1 and 2, combined treatment of the Fray Bentos and Orion discharges could be considered. At the present time, water quality concerns in the Uruguay River include ammonia-nitrogen, phosphorus and fecal coliform, which are primarily suspected to be a result of inadequately treated municipal wastewater. A properly designed combined wastewater treatment facility will decrease the overall loading of these constituents to the river. It would also potentially reduce chemical addition at the treatment facility since nitrogen and phosphorus may need to be added to the Orion wastewater to provide adequate nutrient levels for biological treatment.
- **Provision for Future Tertiary Treatment** - Tertiary effluent treatment to provide supplemental removal has not been proposed for either project, but is normally implemented when the assimilative capacity of the receiving water is small and/or additional removal of target constituents is necessary to achieve site-specific water quality criteria. The need for tertiary treatment has not been requested to date by DINAMA, but this may change. The overall quality of the discharges presented in Table 1-1 represents state of the art secondary treatment and currently meets international standards on a kg/ADT basis. However, it is recommended that the wastewater treatment facilities design for both pulp mills include the provision for a tertiary treatment upgrade to meet potential future DINAMA or IFC requirements, or if future monitoring shows additional treatment would be needed to meet current or future water quality standards.
- **Orion Effluent Diffuser Design Optimization** – The preliminary design for Orion project diffuser is located at a depth of approximately 8.25 meters along the Uruguay River shore and is not located in the deeper main river channel. As discussed in Section 6.1.2, the modeling did not show any amounts exceeding water quality criteria as result of the pulp mill discharges. However, based on the current water quality and river hydrodynamics, sensitivity analyses performed indicate that water quality in a slow-flowing bay area immediately downstream of the proposed Orion plant site is of potential concern and should be carefully monitored. The OSE raw water supply intake for Fray Bentos is located

approximately 3 km downstream from the Orion project site and located 70 m off shore across this small bay. As part of the final design, diffuser enhancements to extend it further into the main channel could provide enhanced dispersion of the effluent into the main river channel. The diffuser discharge location along with the relocation of the OSE water supply intake are possible improvements affecting water quality. If the OSE intake were moved upstream of the Orion discharge, provisions for use of the existing intake under flow reversal conditions in the river should be maintained. Use of a near field dispersion models such as CORMIX or PLUME could be used in support of this evaluation. Alternatively, relocation of the diffuser to a location downstream of this bay area, and the Fray Bentos potable water intake could also be considered. Feasibility studies with required effluent modeling would be needed to evaluate this alternative.

6.3 ADDITIONAL ASSESSMENT RECOMMENDATIONS

Based on the findings of the water quality modeling, consideration should be given to performing following additional assessments:

- **Diffuser Design Optimization** – As described in Section 6.2, an optimization analysis of the Orion project diffuser should be performed using an appropriate near field model to determine if design modification that extend the diffuser farther into the main river channel would provide a higher initial dilution and minimize the potential of future water quality impacts in the bay area downstream of the Orion project discharge and on the OSE water supply intake. This analysis should be integrated with the far-field model developed as part of this study to confirm the effects in the bay area downstream of the Orion discharge as well as other areas downstream. Alternatively, a feasibility study to relocate the Orion diffuser downstream of Fray Bento could also be performed. While the CMB discharge is located in deeper water with better mixing characteristics, no near field modeling has been performed to date. Based on recently proposed CMB diffuser modifications, near field modeling is recommended as part of the final CMB design, to optimize diffuser design and mixing.

- **Future Discharge Mixing/Tracer/Modeling Studies –** Once the discharges are constructed and the pulp mills are in operation, discharge mixing and tracer studies should be performed to confirm the effluent dispersion, mixing and dilution. The mixing and tracer studies should be performed under the average flow, low flow and flow reversal type conditions reviewed in this study. They should also be integrated with the collection of simultaneous water quality data for use in the development and calibration of an enhanced water quality model for the area. This enhanced model could be used to determine future wastewater treatment requirements and the potential impact of new discharges in the area of the projects. In recognition that certain parameters such as phosphorus and ammonia-nitrogen currently exceed water quality criteria, it can also be used in establishing a receiving water quality based effluent permit for all discharges to the Uruguay River, and to advance other water quality management regulatory practices such as establishment of Total Maximum Daily Load based criteria for the Uruguay River.

Figures

Appendix A

Appendix B

Appendix C