Wanganui WWTP – Presentation to Wanganui District Council

28 October 2015

By Humphrey Archer

CH2M Beca reference 6518753/NZ1-11543197

CONFIDENTIAL AND PRIVILEGED

FINAL

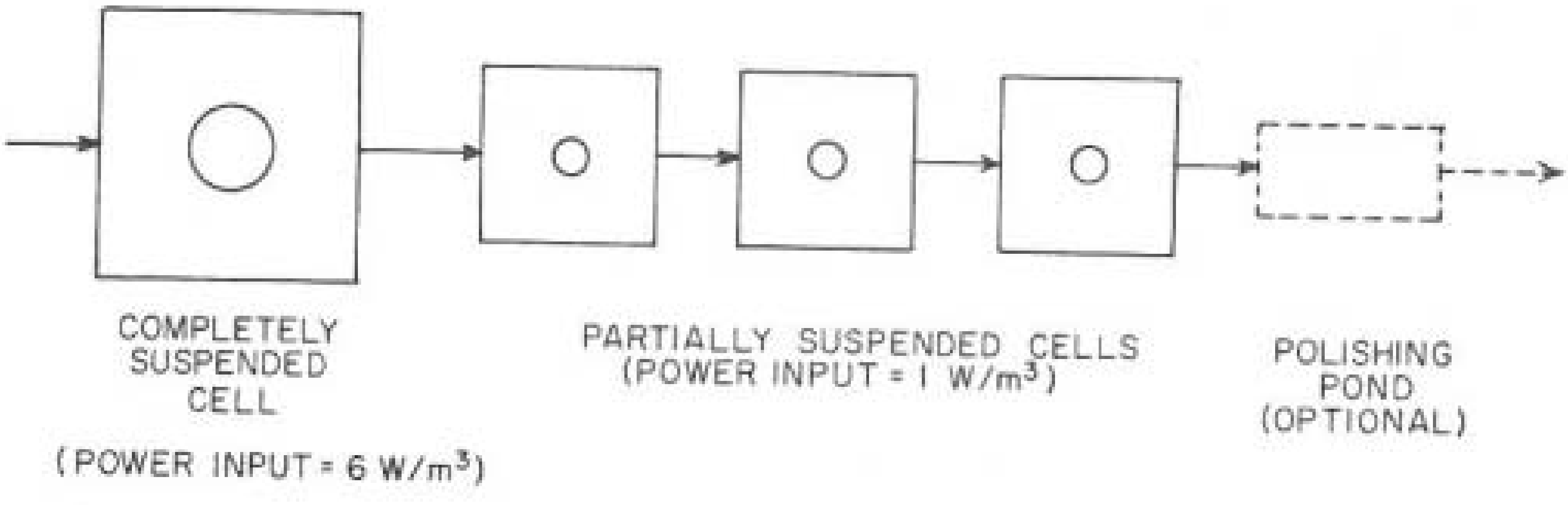
Primary MWH Design Faults In Our Opinion

- Incorrect assumptions in the calculation of required aeration energy for aerobic treatment of the design 90 percentile BOD load
- Excessive energy input to a Facultative Aerated Lagoon (labelled by MWH as the Optimised Lagoon Process – OLP)
- Incorrect assumptions in the calculation of solids mass (sludge) to be stored in the base of the lagoons
- Incorrect assumption of an average 12% solids content in the sludge layer (actual measured value was an average of 3.1%)
- Optimistic interpretation of the mass loads during the design and construction phases and insufficient ‘safety factor’ used
- Secondary design faults are not discussed in this summary

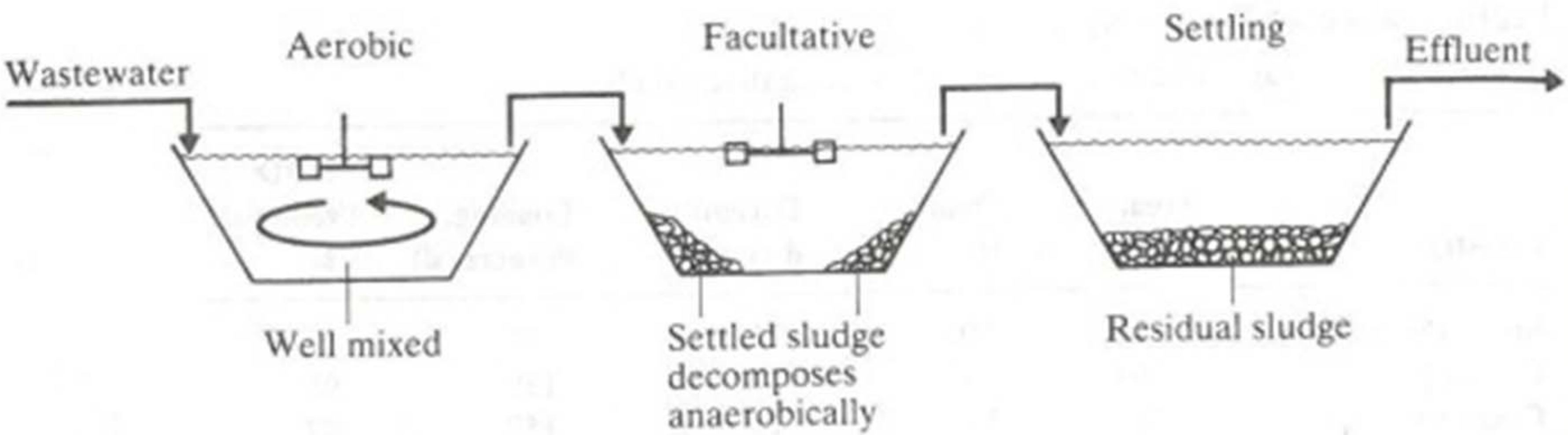
Features of Aerated Lagoons

- So that the significance of technical issues can be appreciated, the types of aerated lagoons need to be explained
- The normal arrangement comprises a fully-mixed aerated lagoon, followed by one to three partially-mixed facultative aerated lagoons-in-series
- Facultative means having ‘two environments’ – an aerobic upper layer and an anaerobic base layer. Another term is a ‘stratified lagoon’

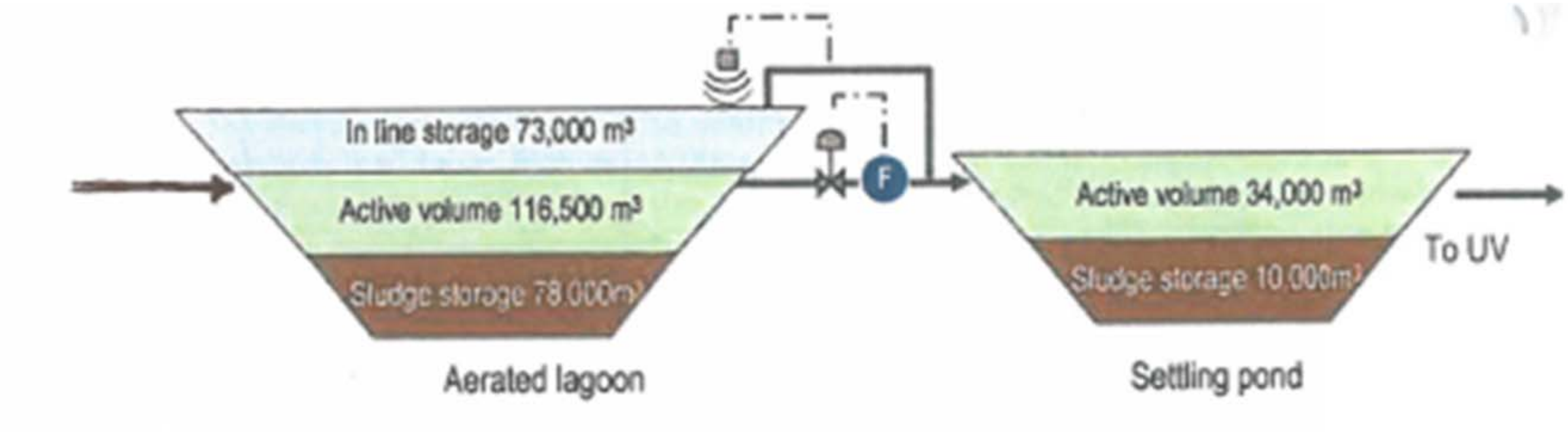
Dual Power Lagoons (Prof Linvil Rich 1980)



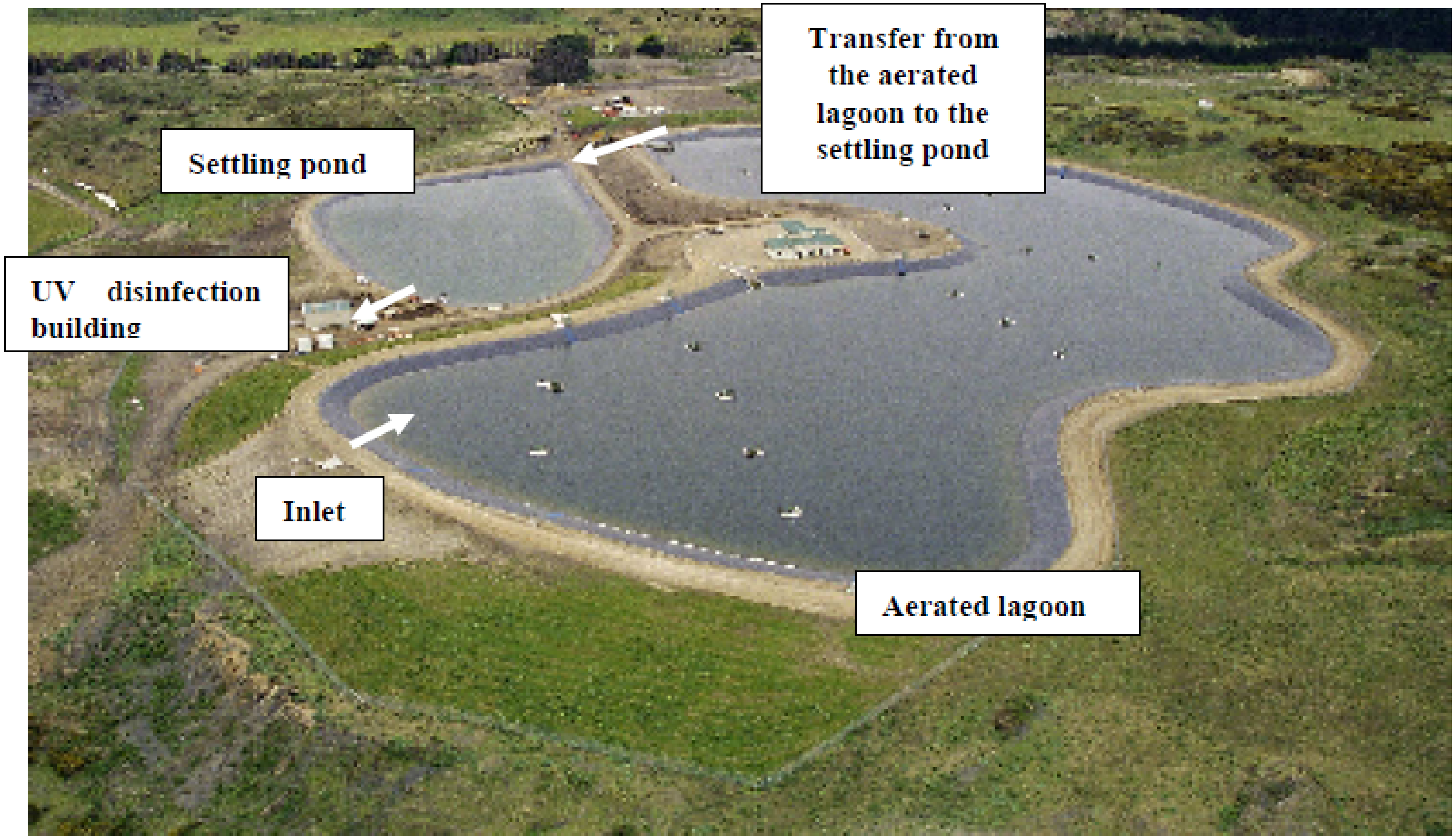
Industrial Wastewater Treatment Lagoons (Eckenfelder 1989)



Wanganui Optimised Lagoon Process (from MWH O&M Manual, Fig 1.4)



Aerial view of the Wanganui Wastewater Treatment Facility prior to commissioning the aerators



Incorrect Assumptions in the Calculation of Aeration Energy

Required Aeration Energy – Calculation Comparisons

Revised Table B1– Aeration Requirement Comparison (Abbreviation of Table B1 in CH2M Beca Review. Differences or uncertainty in assumed values are in red)

Line Ref		MWH Calculation	CH2M Beca Calculation (22/9/15)	CH2M Beca Calculation (14/10/15)
A	90%ile BOD load (kg/d)	23,536	23,536(i)	23,536(i)
C	BOD_5/BOD_L ratio	0.77	0.65	0.65
D	Ultimate mass of BOD treated [A / C] (kg/d)	30,550	36,209	36,209
G	Mass of organisms wasted (kg/d)	13,630	9,600	3,635
H	Daily aeration requirement for BOD reduction [D – G] (kgO_2/d) (kgO_2/h)	16,920 705	26,609 1,109	32,574 1,357
K	Actual Oxygen Requirement (AOTR). Could be 0.6? (kgO_2/kWh)	0.77	0.77(ii)	0.77(ii)
L	Installed power required [H / K] (kW) (with no diurnal peaking factor)	**915**	**1,440**	**1,763**
N	Benthic oxygen demand at 80g/m².d and 20,000m² (iii) (kgO_2/d) (kgO_2/h)	Not calculated	1,600 67	1,600 67
P	Installed aeration power required for benthic load (kW)	Not calculated	93	93(iv)
S	Overall peak aeration demand (BOD removal and benthic demand) at high BOD loadings (kgO_2/d) (kgO_2/h)	16,920 705	28,209 1,175	34,174 1,424
T	Overall installed aeration power (kW) (required for BOD removal and benthic oxygen demands, with no diurnal peaking factor applied)	**915**	**1,526**	**1,850**

i. From MWH calculations supplied to WDC on 13 December 2007 – MWH.02058.00

ii. MWH value assumed. This could be optimistic given that testing did not achieve the target.

iii. Rich (1980) assumes the 80 g/m².d value. 20,000m² area at top of sludge layer, is estimated from Section 6.2, MWH Report 11

iv. If the Eckenfelder method is used, Benthic oxygen demand in summer = 40% of soluble BOD_L , which would be 9,120 KgO_2/d or 380 KgO_2/hr. This would require an extra 493 kW aeration power for the benthic demand alone – not included above.

Comments on Aeration Energy Calculations

- Aeration calculations were not included in MWH Reports 10 and 11
- The 2004 Peer Reviewers requested the aeration calculations, but these were not provided by MWH
- Aeration calculations were sent to WDC on 13 December 2007 – about six months after the plant start-up
- MWH adopted optimistic values for a number of factors, which resulted in a substantial difference in aeration power required (MWH = 915 kW vs CH2M Beca estimates of 1,526 kW to 1,850 kW)
- MWH also did not include the ‘feedback’ oxygen demand from the sludge layer

Excessive Energy Input to a Facultative Aerated Lagoon

Excessive Energy Input to a Facultative Aerated Lagoon

- The purpose of a facultative aerated lagoon is to have a quiescent layer at the base, where organic solids can be stabilised by anaerobic digestion (which converts solids to biogas thus reducing the mass solids)
- To avoid disturbance of the base layer, energy input at the surface is limited to 2 W/m^3, based on the aerobic zone volume (Rich 1983)
- For Wanganui, the aerobic volume was approximately 116,000m^3, so the installed power should have been a maximum of 232 kW

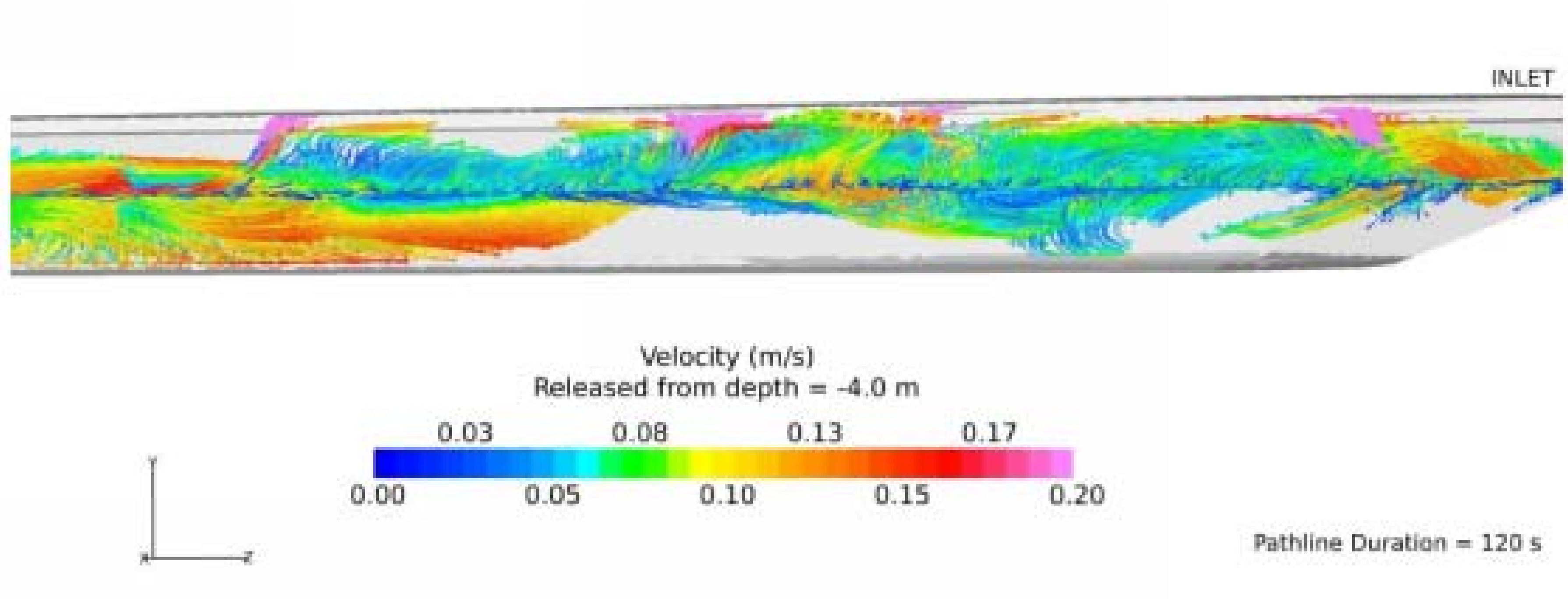
Excessive Energy Input to a Facultative Aerated Lagoon (cont'd)

- MWH calculated required power at 915 kW and initial installed power (Tornados) was 17 x 45 kW = 765 kW (excluding the boost blowers which do not contribute to mixing) – From July 2007 start-up
- Increased power with 20 Twisters and 3 Tornado, was 23 x 45 kW = 1035 kW – From July 2009
- The CH2M Beca estimate for aeration power is 1,526 kW or 1,850 kW (see revised Table B1 earlier)
- This is 6 to 8 times the allowable power to avoid disturbing the base layer
- More aerators would have disturbed the base layer

Depth of the Aerated Lagoon

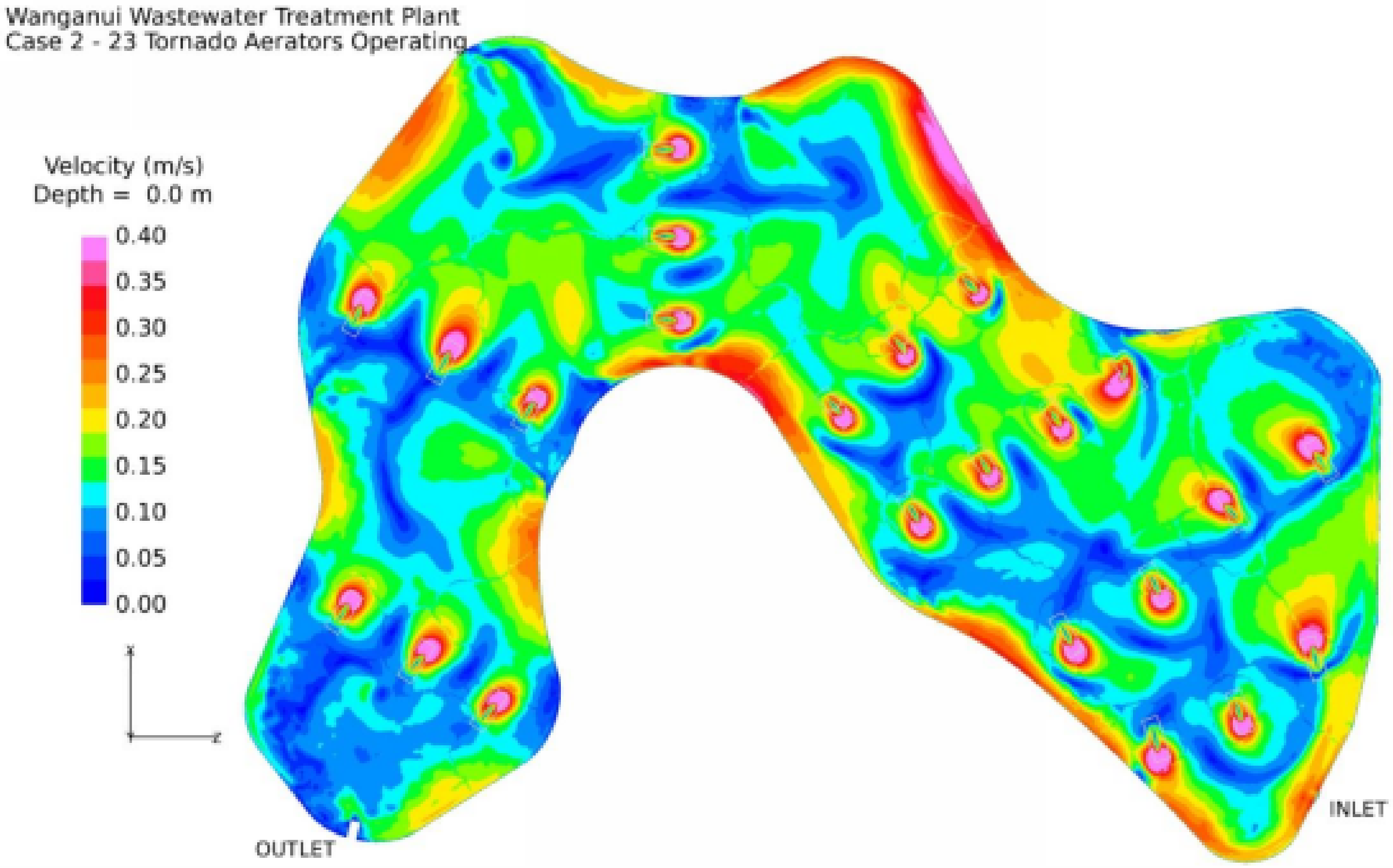
- The main aerated lagoon has a normal water depth of 8 m and maximum of 10 m for peak wet weather flow storage
- Lower 4 m was designed for sludge storage
- Upper aerobic zone was 4 m deep
- Typical facultative aerated lagoons are 4 to 5m total depth
- Did the extra depth allow the sludge layer to be undisturbed?
- WDC commissioned a Computational Fluid Dynamics (CFD) study of the mixing currents in the aerated lagoon

Fig 3-12 Case 1 – 120s pathlines released from 4m depth (17 Tornados)



CFD Modelling Results for Mixing of the Aerated Lagoon (Figures from CFD Design & Engineering Report Oct 2015)

Fig 3-14 Case 2 – Surface Velocity Contours (23 Tornados)



CH2M Beca

Fig 3-20 Case 2 – 120s pathlines released from 4m depth (23 Tornados)

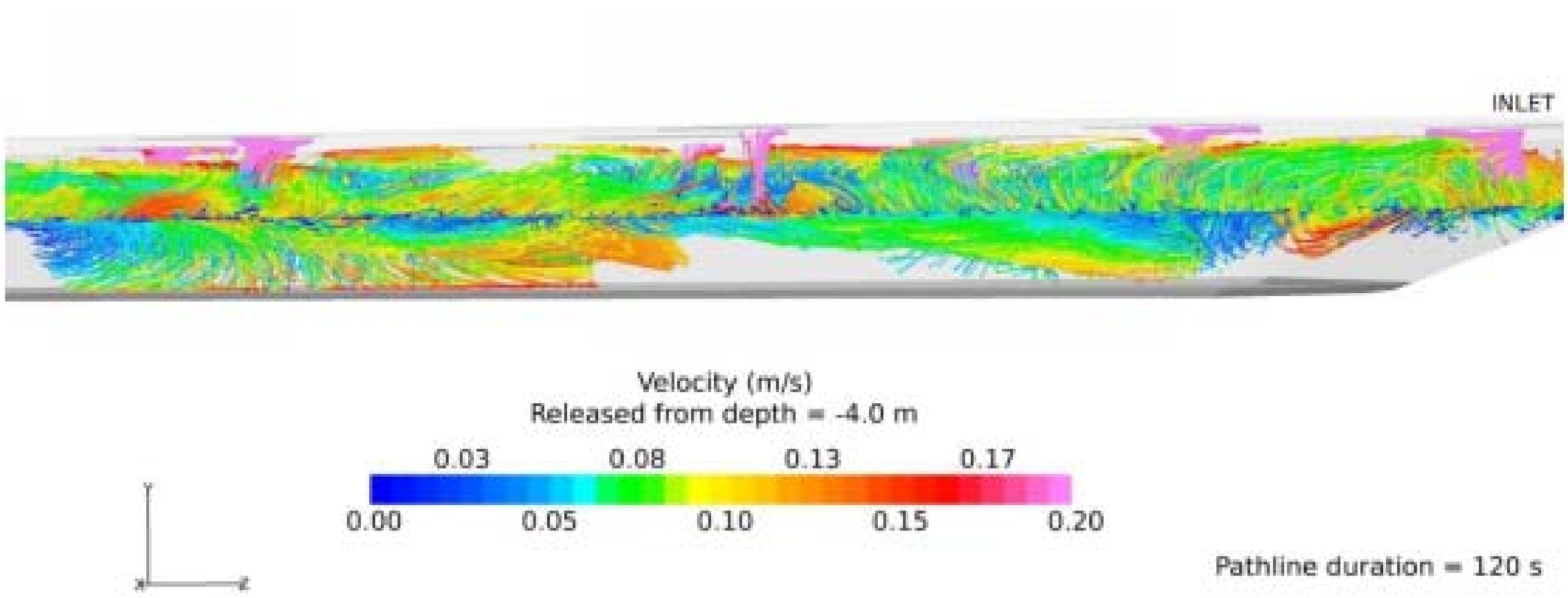


Fig 3-22 Case 3 – Surface Velocity Contours (20 Twisters & 3 Tornados)

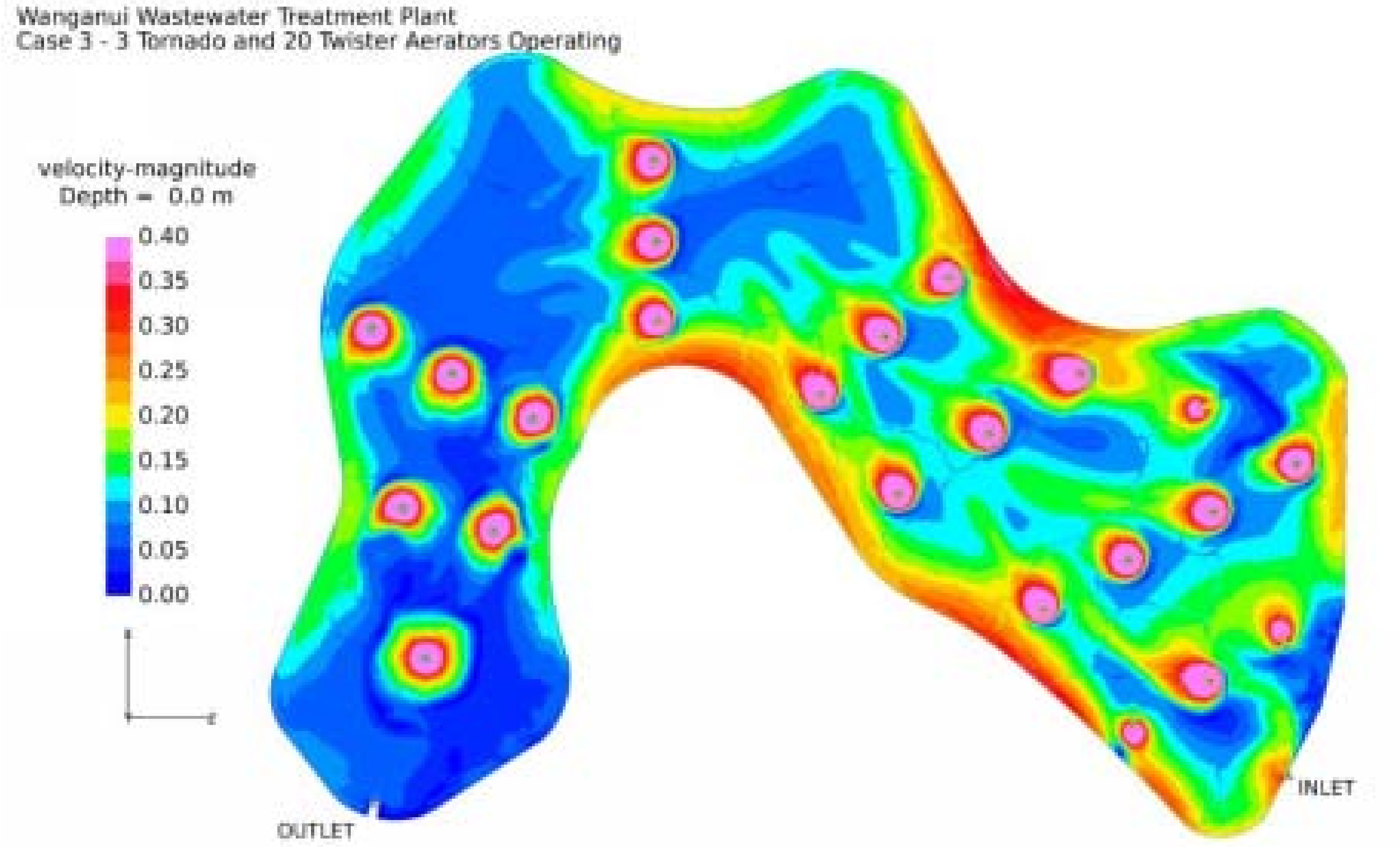


Fig 3-28 Case 3 – 120s pathlines released from 4m depth

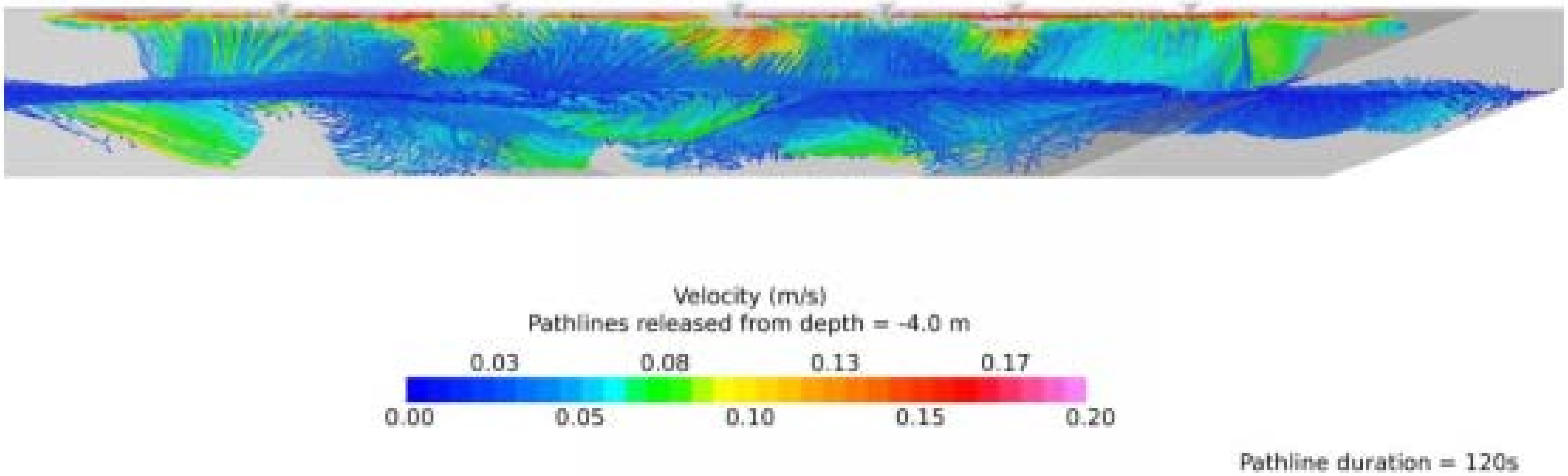


Fig 3-29 Case 3 – Location of Aerator Rows 2 and 5

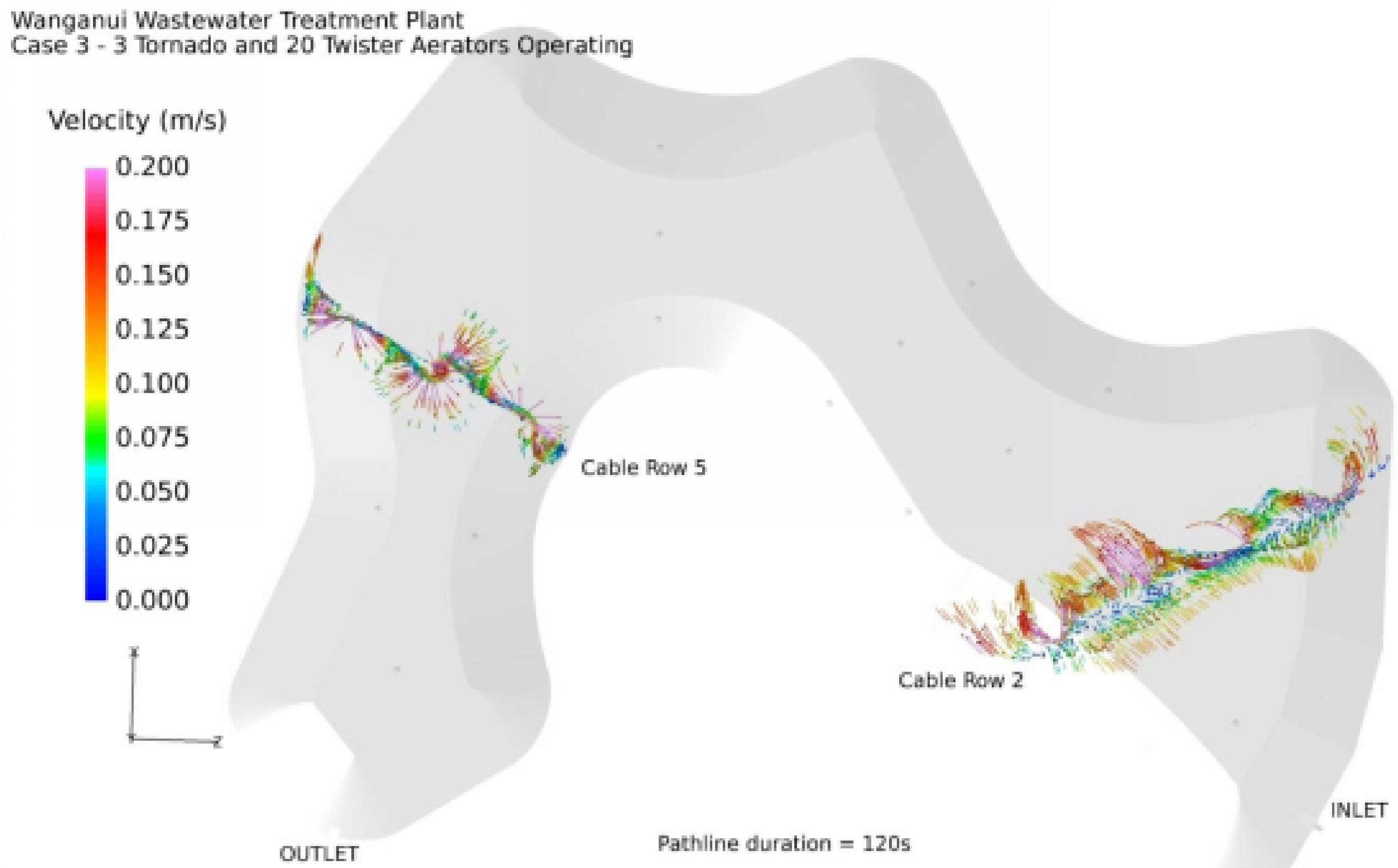
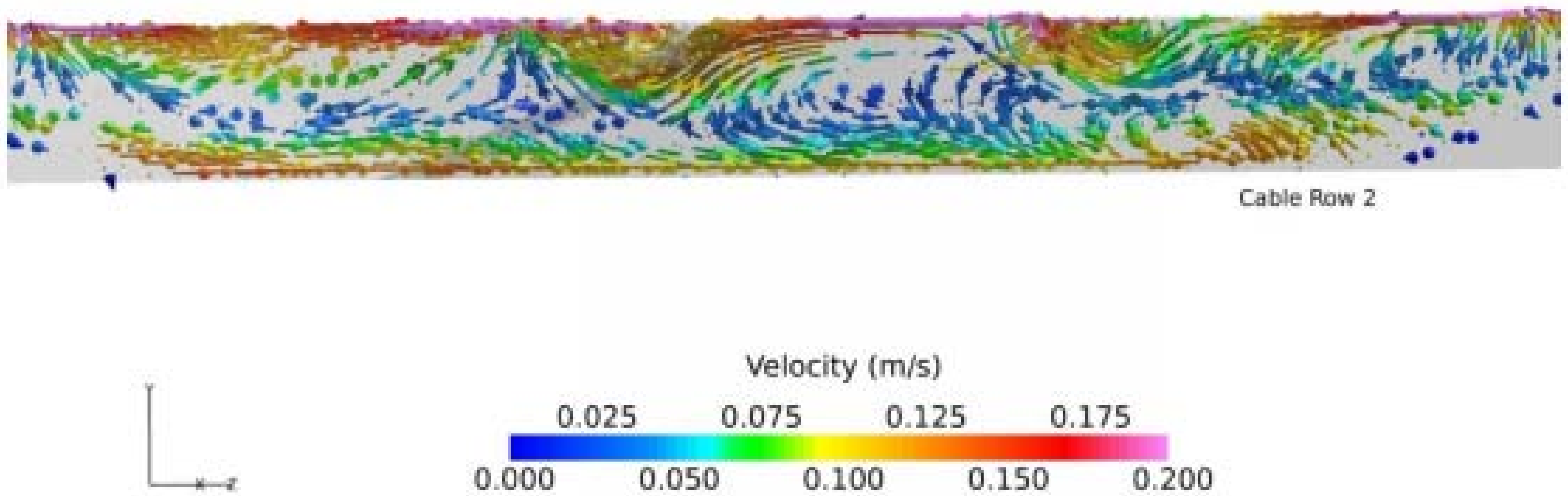


Fig 3-30 Case 3 – Streamlines through full 8m depth along Aerator Row 2



Twister Aerator with Sludge Uplift

Twister Aerator with Clean Water

CFD Modelling Conclusions

- The mixing currents from the Tornado and Twister aerators extended below the 4 m plane (interface of aerobic and anaerobic zones)
- These currents would have entrained gas-buoyed sludge and carried it into the upper aerobic zone causing increased oxygen demand, or carried oxygen into the anaerobic zone causing incomplete anaerobic digestion
- Stabilised and well-consolidated sludge may not have been entrained by the deeper currents, but as the sludge surface rose, more sludge would have been disturbed
- CFD modelling supports the guideline value for mixing energy input limit of 2 W/m^3

Sludge Storage Incorrect Assumptions

Sludge Storage Calculation

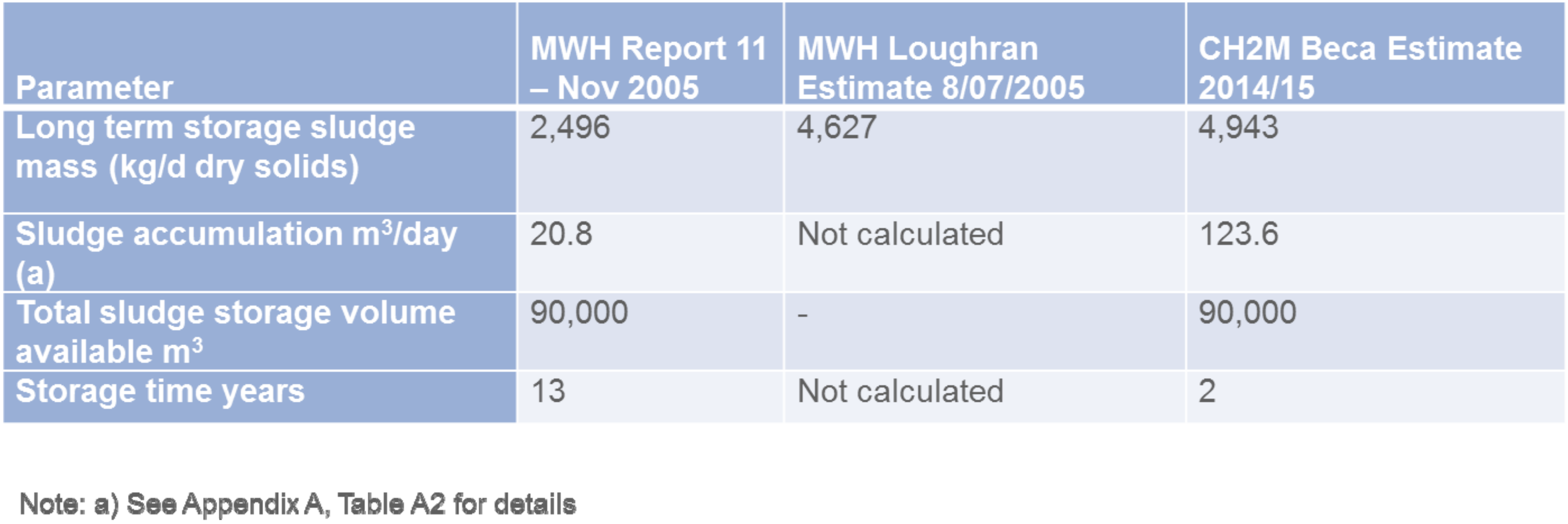
- The key reason for selecting the ‘Optimised Lagoon Process’, was the expected ‘20 years sludge storage’, first stated in Report 10 (2003)
- However, the sludge storage volume of 160,000m^3 in Report 10, was reduced to approximately 90,000m^3 in Report 11 (2005), and an ‘as-built’ of 78,000m^3
- The reduction in available sludge storage volume was not highlighted in Report 11 (Nov 2005)
- Report 11 in Section 7.4, predicts 13 years sludge storage in the aerated lagoon and 8 years for the settling lagoon
- The O&M Manual (2010) and a 2008 Conference paper by MWH, re-stated the predicted 20 years sludge storage

Comparison of Sludge Consolidation Factors (Table 4-1)

Location	Sludge Dry Solids Content
MWH Report 10 – assumption for Wanganui	12.0%
MWH Report 11, Section 7.4.2 – assumption for Wanganui	12.0%
MWH Report 11, Section 7.5 (Regina, Canada aerated lagoons)	7.5% and 7.14%
MWH Report 11, Section 7.5 (Meze, France anaerobic lagoon)	8.0%
Dual Power Lagoons USA (L. Rich, 2003)	Range from 4.8% to 7.4% at base of lagoons after typically 15 years storage
Hawera Anaerobic Lagoon (meat processing wastewaters)	3.4% (weighted average)
Wanganui (measured by Cardno-BTO May 2013) **Aerated Lagoon** **Settling Lagoon**	3.1% (average) 1.6% (average)
Loughran MWH	6 to 8%
Hoffmann MWH	3 to 5%

- The 2004 Peer Reviewers questioned the Report 10 12% consolidation factor but MWH replied with anaerobic lagoon examples (with no surface aeration)
- The Dual Power Lagoon range from 4.8% to 7.4%, would have been more appropriate in our opinion

Summary Comparison of Sludge Volume Estimates (Table 4-2)



Parameter	MWH Report 11 – Nov 2005	MWH Loughran Estimate 8/07/2005	CH2M Beca Estimate 2014/15
Long term storage sludge mass (kg/d dry solids)	2,496	4,627	4,943
Sludge accumulation m^3/day (a)	20.8	Not calculated	123.6
Total sludge storage volume available m^3	90,000	-	90,000
Storage time years	13	Not calculated	2

Note: a) See Appendix A, Table A2 for details

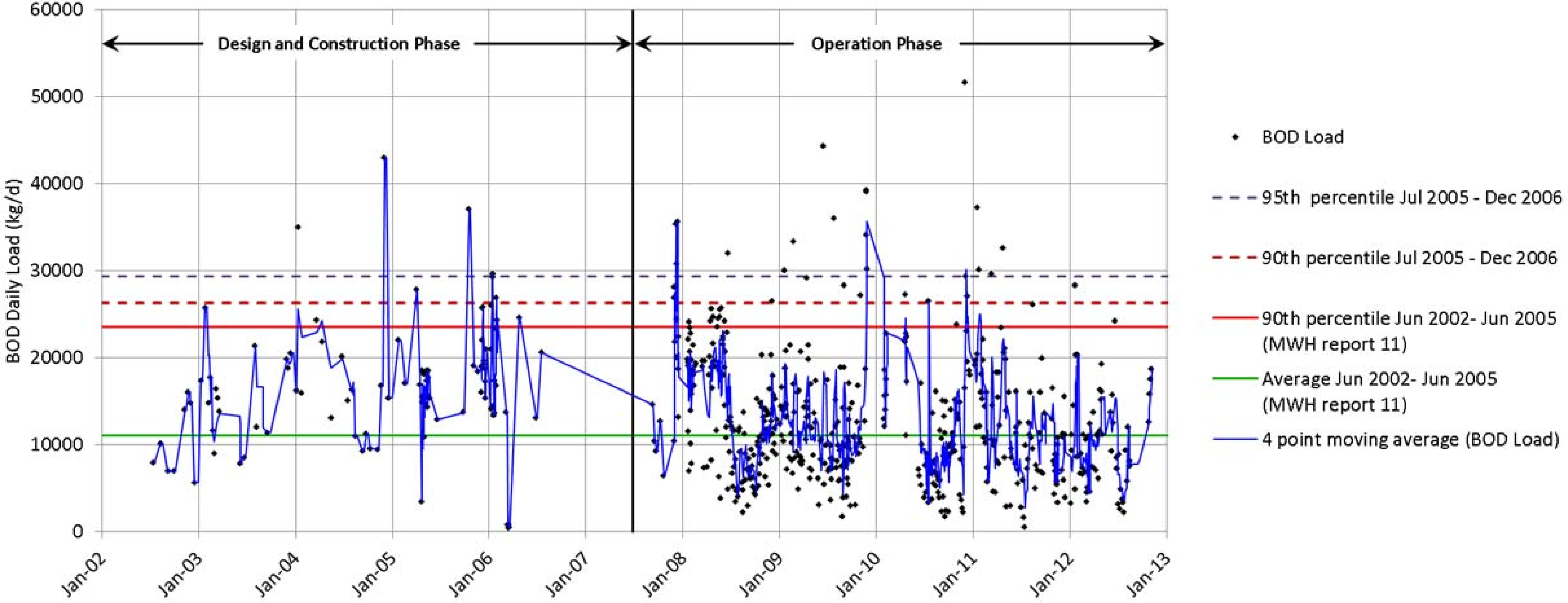
Sludge Storage Conclusions

- The CH2M Beca estimate is 2 years sludge storage. The difference in estimated storage time is due to the combination of differences in the sludge mass load and the sludge consolidation factor
- MWH internal review recommendations were:
  - Loughran (MWH) estimated a significantly greater mass of solids – 4,627 Kg/d compared to 2,496 Kg/d in MWH Report 11
  - Loughran (MWH) recommended sludge consolidation to 6% or 8%, compared to 12% in MWH Report 11
  - Hoffmann (MWH) recommended sludge consolidation in the range 3% to 5%, compared to 12% in MWH Report 11
  - Report 11 does not explain why the Loughran and Hoffman recommendations were not adopted
- Also, the 2004 Peer Reviewer’s concerns were not adequately addressed

Load Characterisation

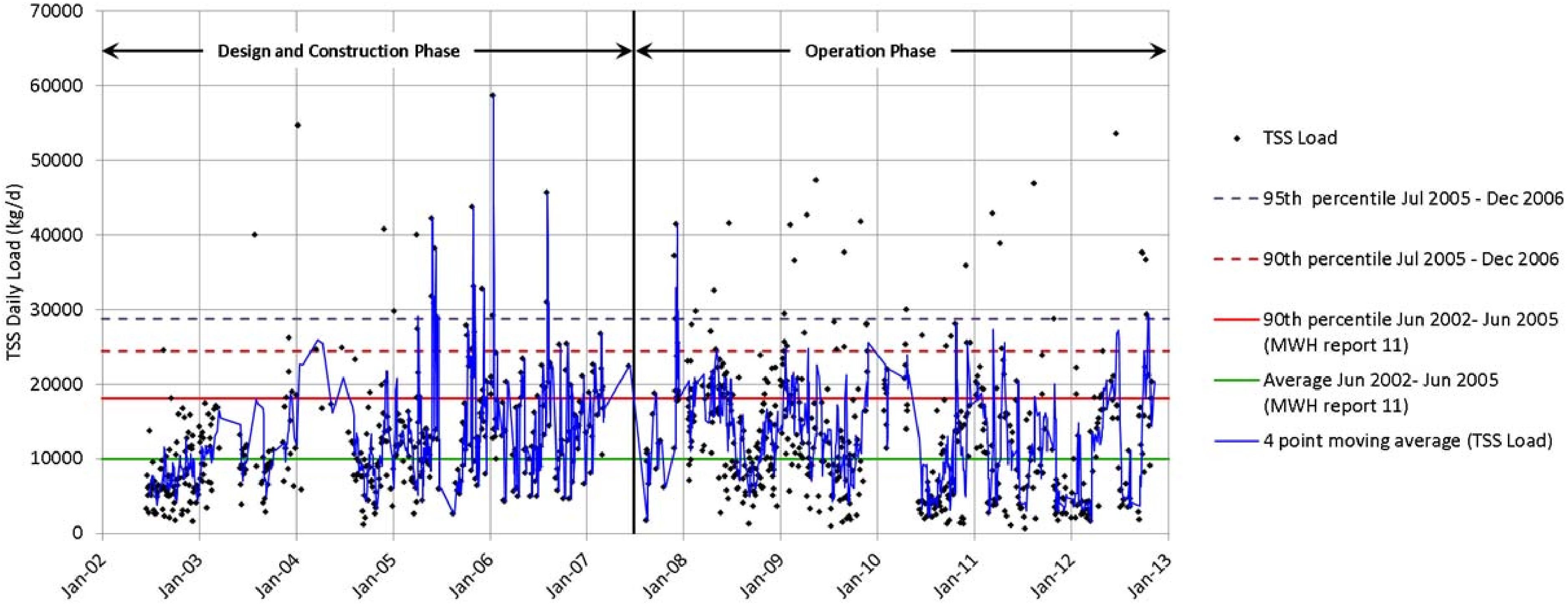
Full load as measured at the Beach Road Pump Station (BRPS) before bypass to Ocean Outfall

Full BOD Daily Load at Beach Rd Pump Station



CH2M Beca

Full TSS Daily Load at Beach Rd Pump Station



Effects of Bypass to the Ocean Outfall During Operation from 2007

Loading Comparisons (for full year data); Accounting for Bypass to Ocean Outfall

		2007	2008	2009
	Average Design Value	WWTP Inlet	WWTP Inlet	WWTP Inlet
Flow	32,000	22,178	15,259	26,881
TSS Load	10,000	12,033	6,742	11,957
BOD Load	11,000	13,092	7,026	10,686
COD Load		20,783	15,823	30,126
BOD % above average design load		19%	-36%	-3%
TSS % above average design load		20%	-33%	20%

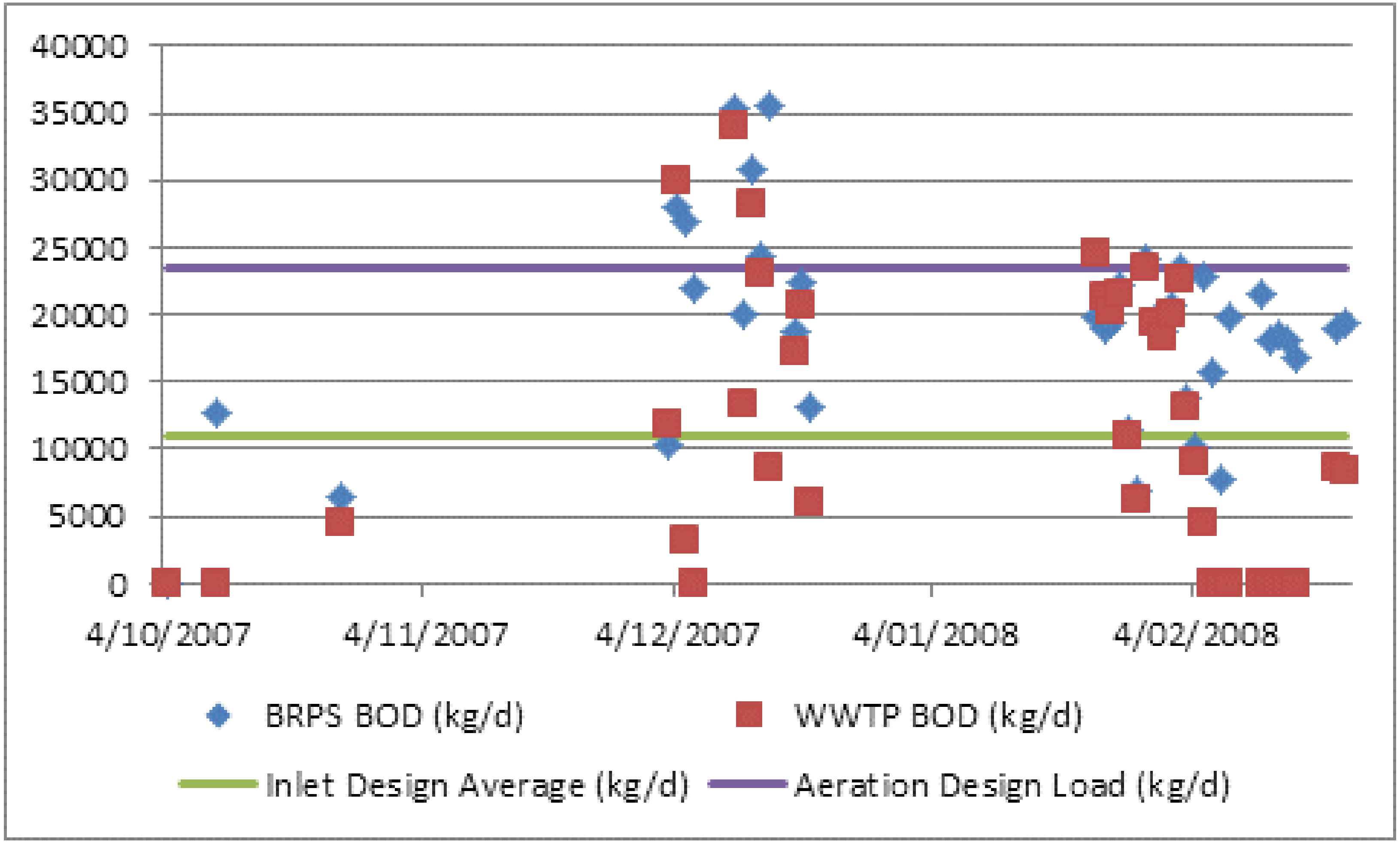
- The overall **average BOD** load for 2007 was higher than the design value, but much lower in 2008 and about the same in 2009, and similar for TSS (except 2009 where it's very high overall).
- Note that these are average values. The design 90%ile BOD value was generally not exceeded – see next slide.

Loading Comparison (peak season 90 percentile loads); Accounting for Bypass to Ocean Outfall

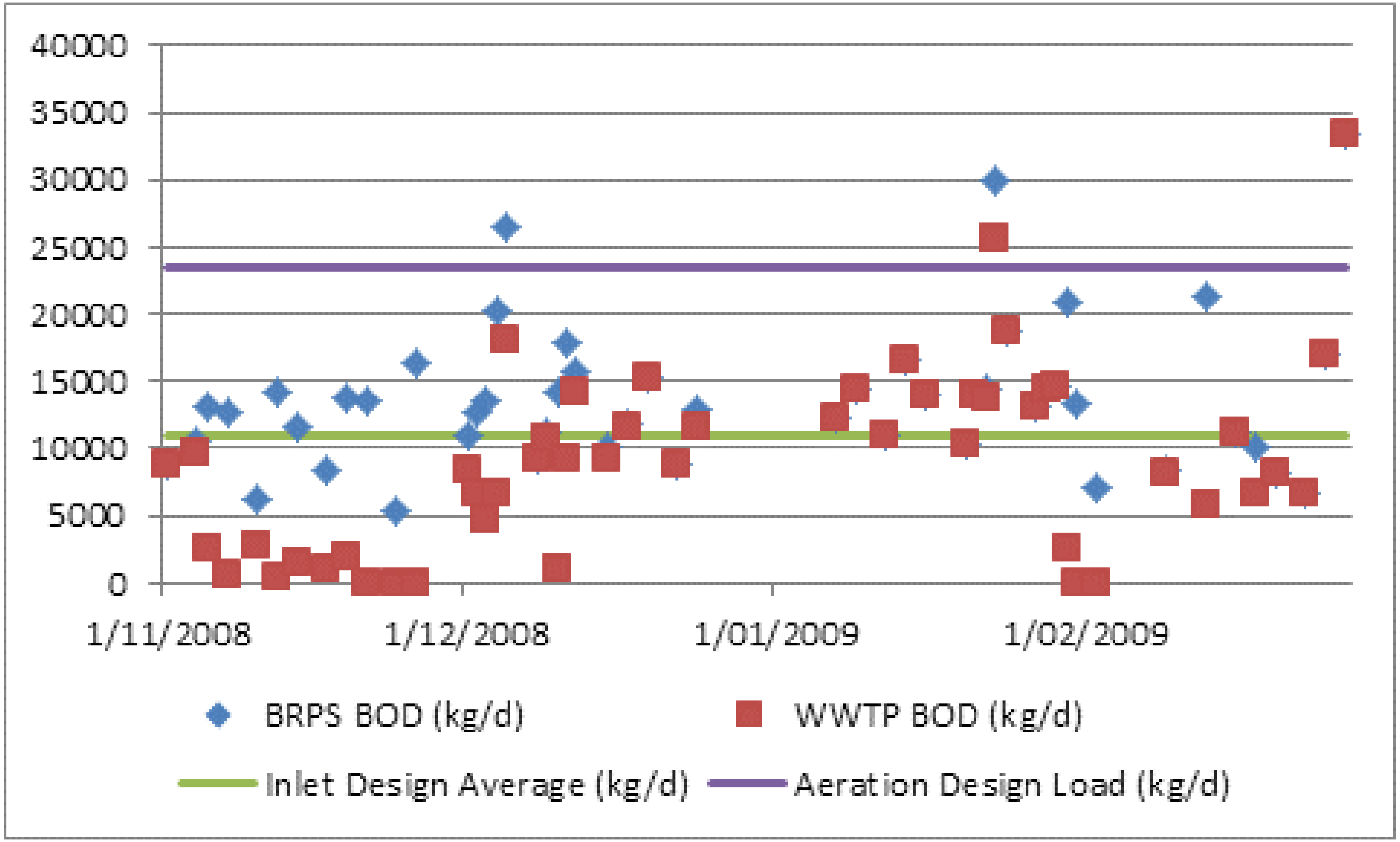
		2007/2008	2008/2009	2009/2010
	Design Loads	**WWTP Inlet**	**WWTP Inlet**	**WWTP Inlet**
Average TSS	10,000	11,552	10,678	16,070
90%ile TSS		20,218	22,670	25,392
Max TSS		39,966	36,596	52,721
Average BOD	11,000	12,452	9,168	12,942
90%ile BOD	23,536	23,944	16,573	25,391
Max BOD		34,097	33,358	52,721
Average BOD % above design load		13%	-17%	18%
90%ile BOD % above design load		2%	-30%	8%

- We have assumed the peak season is from November 1 to February 28

Peak Season 2007/08 BOD Loads on WWTP

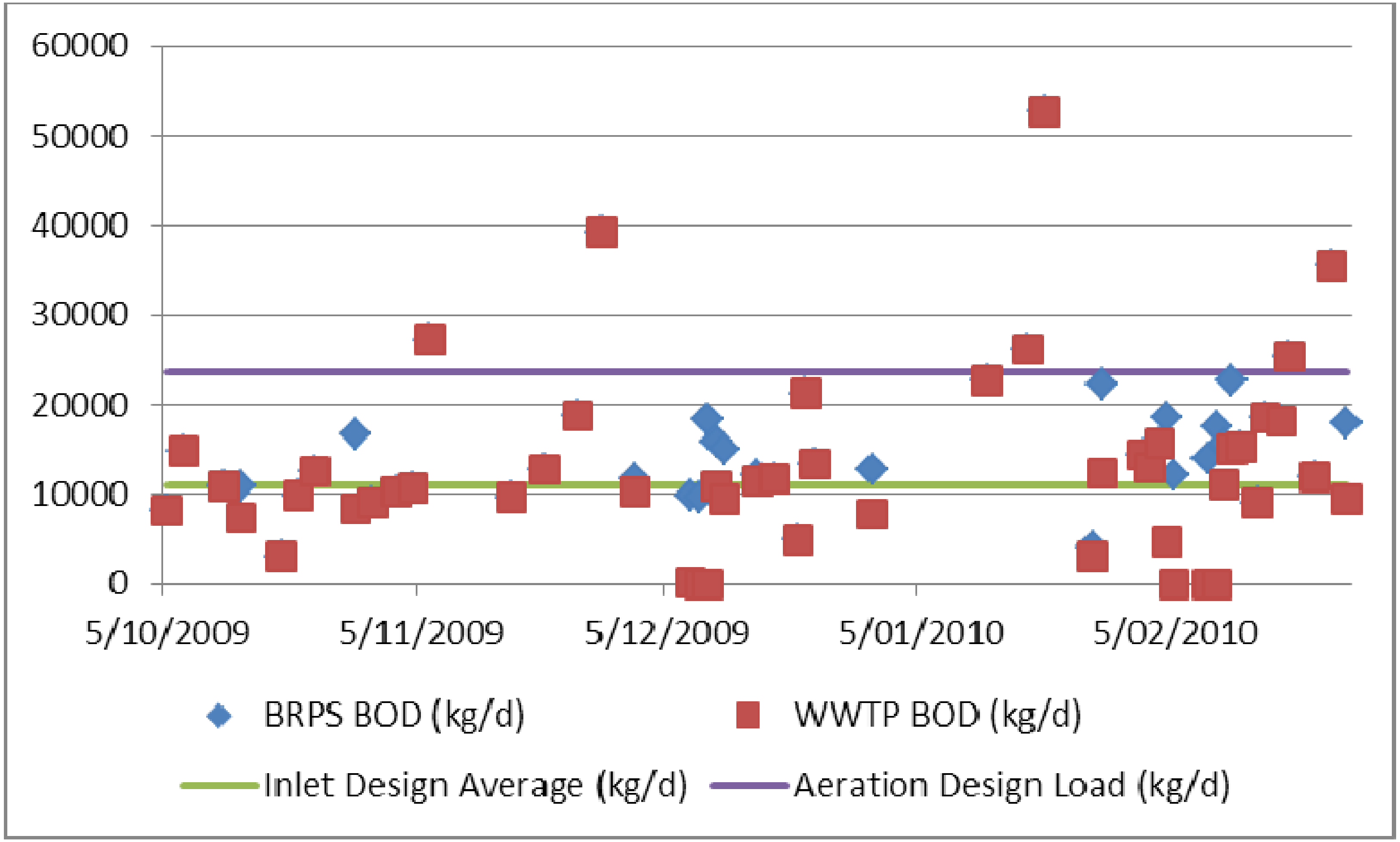


Peak Season 2008/09 BOD Loads on WWTP



CH2M Beca

Peak Season 2009/10 BOD Loads on WWTP



CH2M Beca

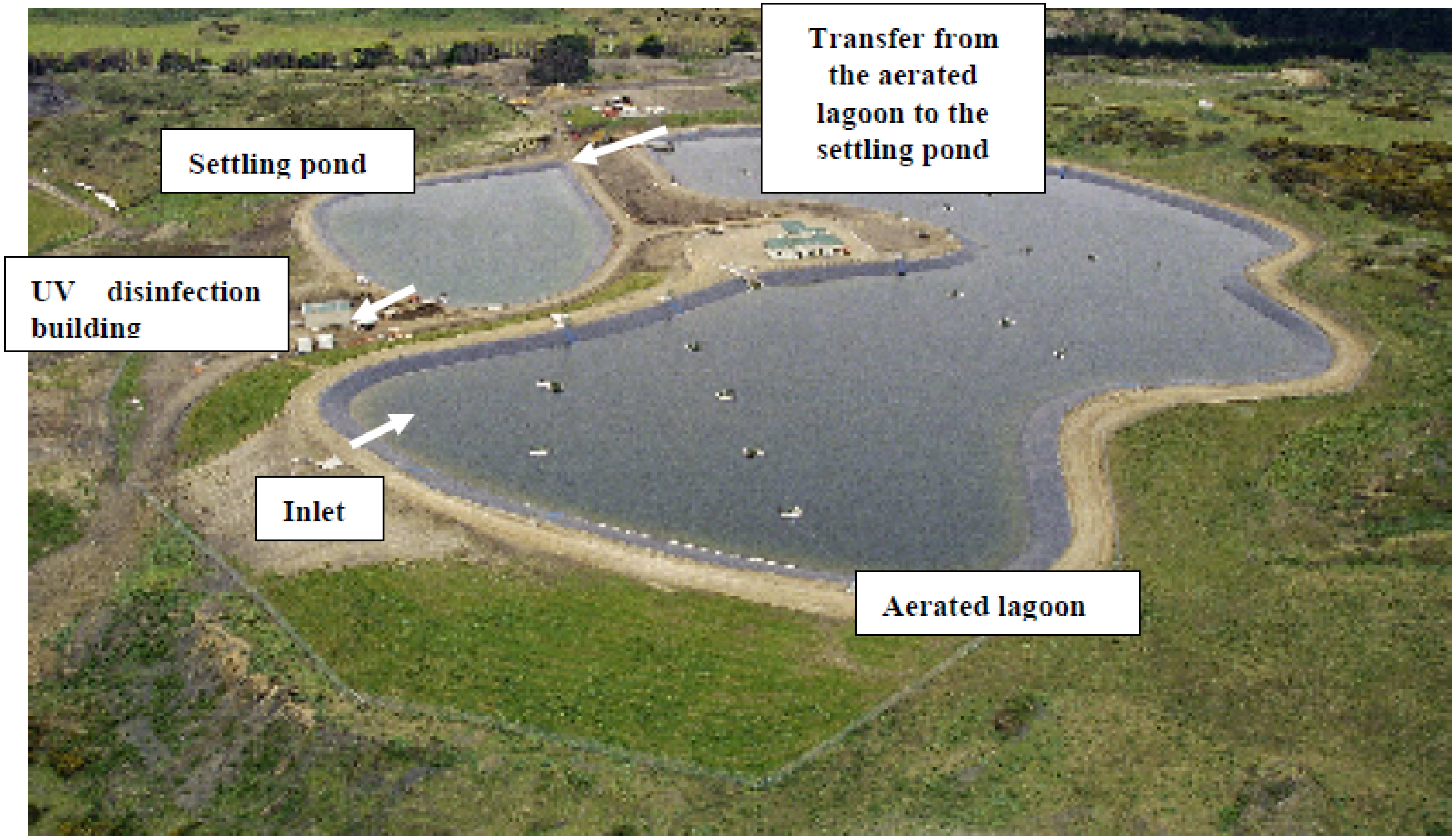
Actual Load on WWTP due to Bypassing to Ocean Outfall

- It is expected that 1 in 10 values would be greater than the 90 percentile design load
- There are some points above the 90 percentile aeration design load in 2007/08, but few in the next few seasons.
- By using the bypass to the ocean outfall, WDC protected the plant from higher BOD loadings during peak processing seasons.

Overall Conclusions in Our Opinion

- The “Optimised Lagoon Process” did not have precedents, and attempted to combine all treatment functions into one lagoon
- Significant errors were made in the estimated sludge storage volume which resulted in the storage capacity being exceeded from about 2009/10
- Required aeration energy was significantly underestimated and no margins were applied (which is standard practice for aeration demand)
- Installed aeration energy disturbed the sludge layer and prevented full anaerobic digestion of the sludge. Further aeration would have caused more disturbance of the sludge layer.
- The concerns expressed by the 2004 Peer Reviewers were not appropriately addressed by MWH

Questions


Transfer from the aerated lagoon to the settling pond
Settling pond
UV disinfection building
Inlet
Aerated lagoon

Additional Slides

Peer Reviewers Main Concerns in 2004

- *"The panel considers a number of the issues raised have not been adequately addressed. We raise what we consider to be five key points for further action or attention as follows:*
  - *The need for a rigorous risk assessment process covering the preferred option, the sewer separation process and trade waste dischargers;*
  - *Provision of calculations used for determining the proposed aeration requirements;*
  - *Provision of raw data to support claims made;*
  - *Confirmation of the longevity of the plant, particularly in terms of sludge inventory (refer to Section 8 of the query table);*
  - *The need to formalise the trade waste bylaw and trade waste agreements with significant dischargers to ensure adequate control of discharges is enforceable."*

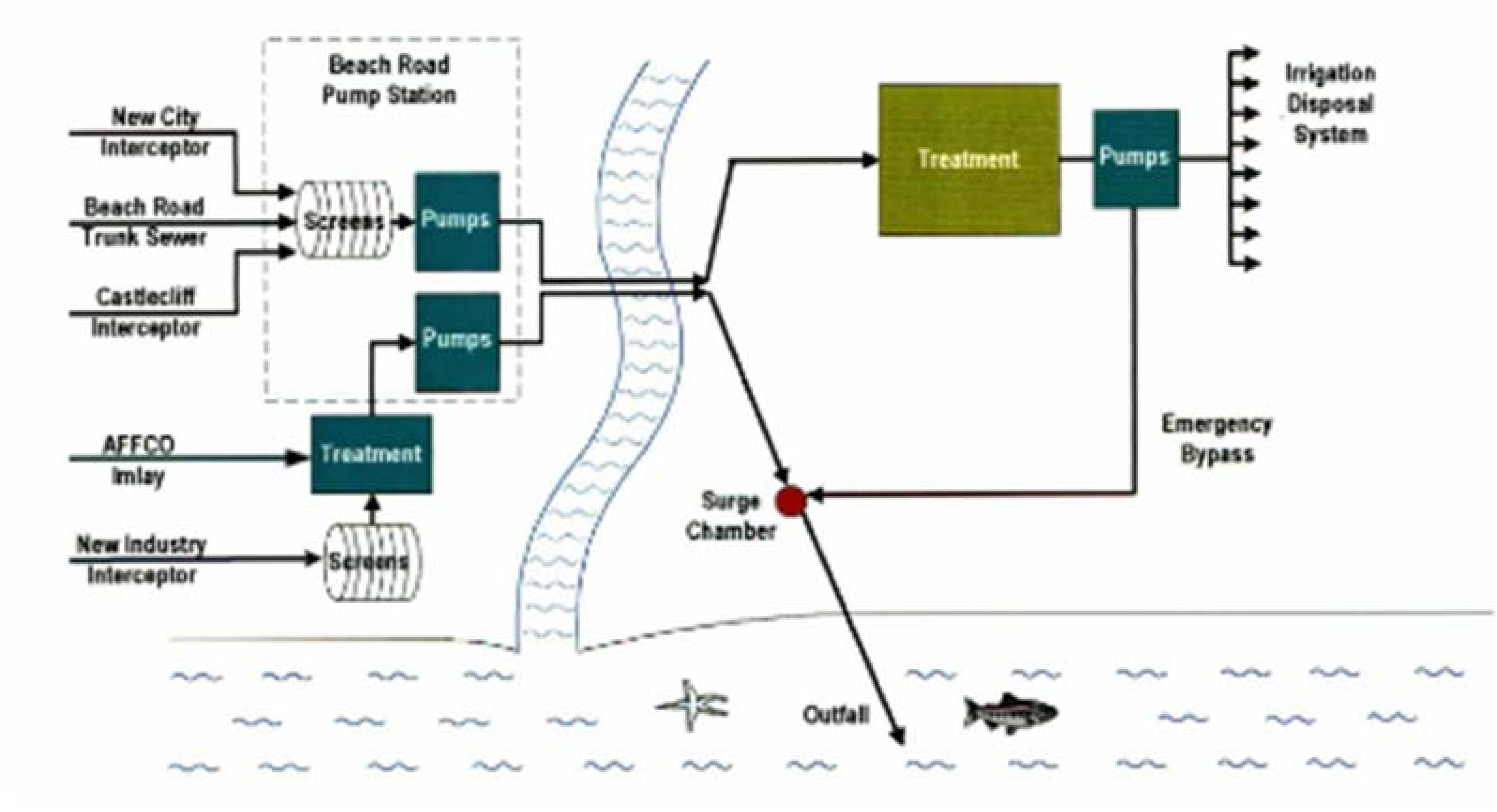
Comment

- In the time available for this review, it has not been possible to determine the actions taken regarding the five matters listed above.
- It appears that the Peer Review Panel was not reconvened to review the Confirmed Process Design Report (MWH Report 11, October 2005), nor later design documentation.

Table 5-1 Wanganui WWTP Effluent Monitoring Results Summary (2009 – 2012)

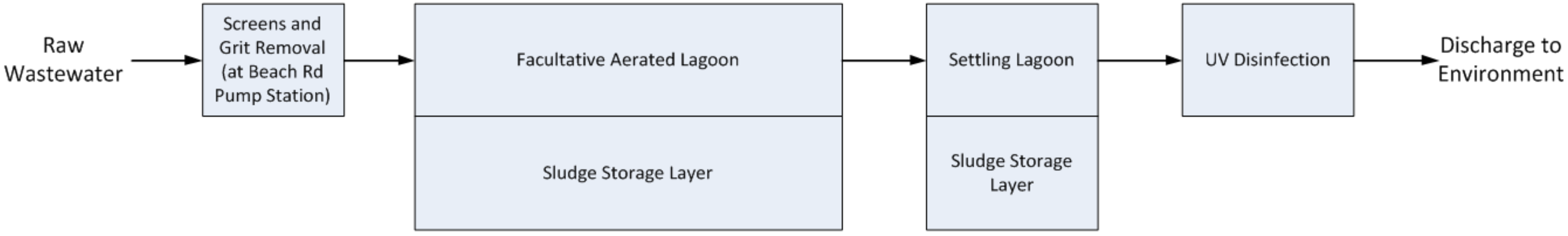
Parameter	Units	Basis	2009	2010	2011	2012	Resource Consent Standard
BOD	g/m^3	Median	76	121	84	80	n/a
TSS	g/m^3	Median 95 %ile	99 222	89 212	159 241	184 390	n/a 100
Enterococci	cfu/100ml	Median Maximum	3,900 160,000	20,000 2,100,000	24,000 1,600,000	51,000 620,000	4,000 12,000
Faecal Coliforms	cfu/100ml	Median 90 %ile	7,500 56,600	22,000 91,000	86,000 300,000	260,000 501,000	10,000 25,000

Figure 2-1 The 1992 Wastewater Scheme (from the AEE Summary March 2001)



CH2M Beca Review Report
Appendix D Flow Diagrams

Comparisons of Wanganui to Other Aerated Lagoon Treatment Plants Referred to by MWH



Raw Wastewater

Screens and Grit Removal (at Beach Rd Pump Station)

Facultative Aerated Lagoon

Sludge Storage Layer

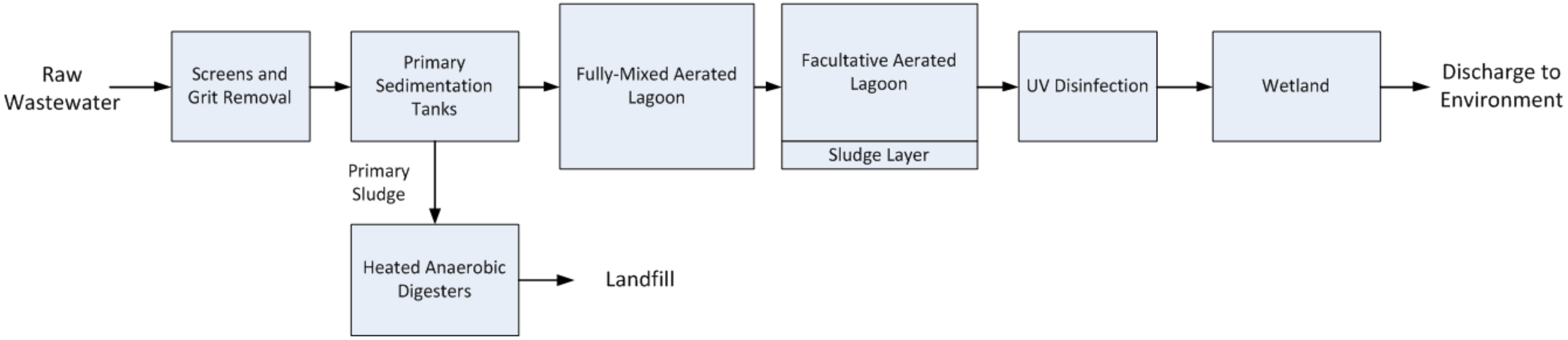
Settling Lagoon

Sludge Storage Layer

UV Disinfection

Discharge to Environment

Wanganui WWTP Flow Diagram (Municipal plus major industries)



Raw Wastewater

Screens and Grit Removal

Primary Sedimentation Tanks

Primary Sludge

Heated Anaerobic Digesters

Landfill

Fully-Mixed Aerated Lagoon

Facultative Aerated Lagoon

Sludge Layer

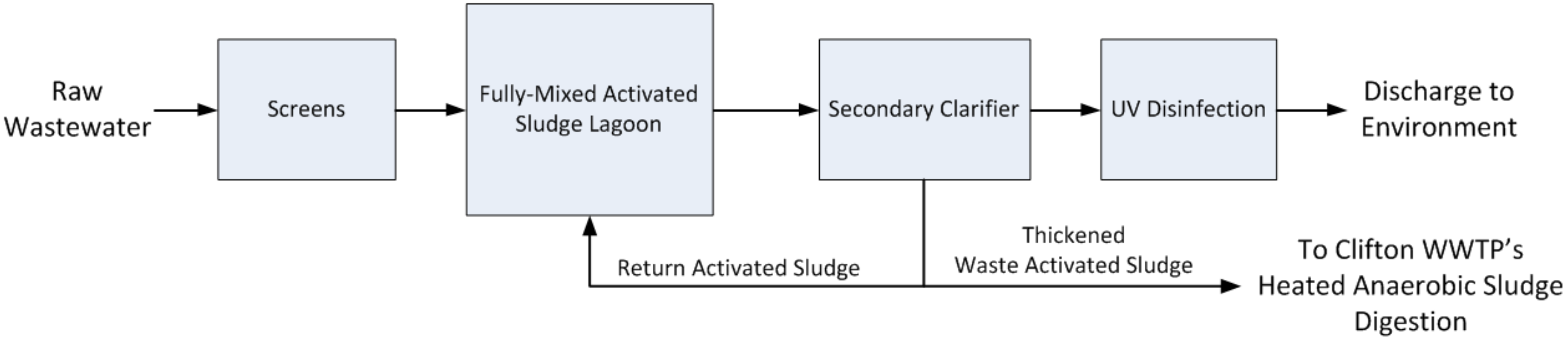
UV Disinfection

Wetland

Discharge to Environment

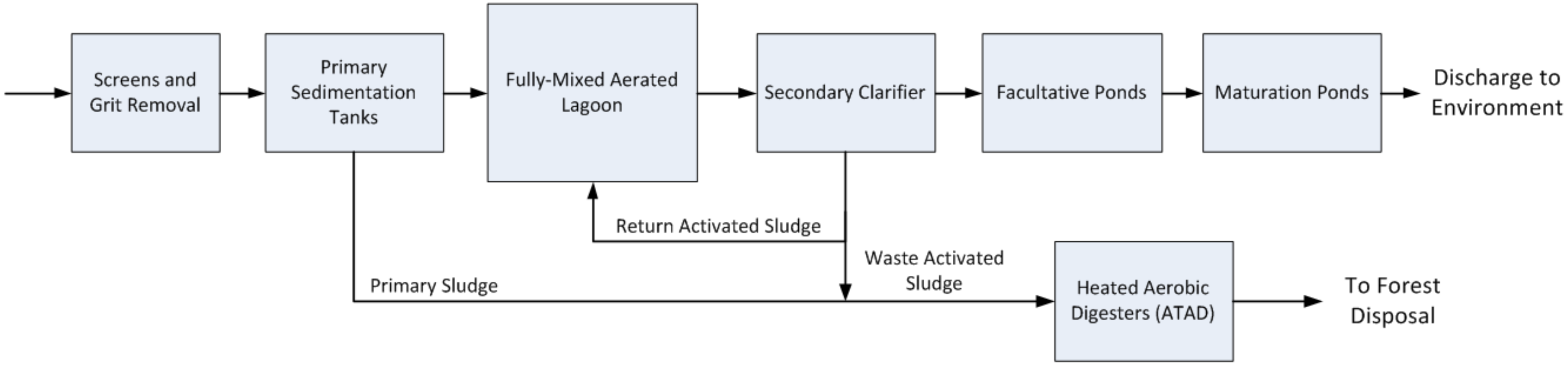
Palmerston North WWTP Flow Diagram (Municipal)

Comparisons of Wanganui to Other Aerated Lagoon Treatment Plants Referred to by MWH



Raw Wastewater
Screens
Fully-Mixed Activated Sludge Lagoon
Secondary Clarifier
UV Disinfection
Discharge to Environment
Return Activated Sludge
Thickened Waste Activated Sludge
To Clifton WWTP's Heated Anaerobic Sludge Digestion

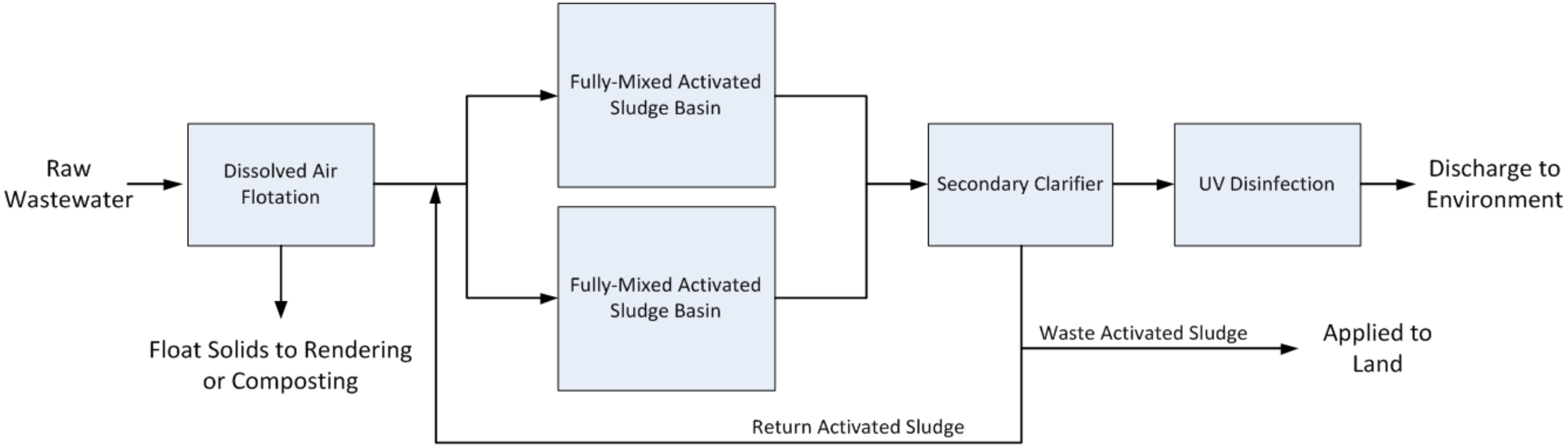
Bluff WWTP Flow Diagram (Municipal plus Seafood Processing Industries)



Screens and Grit Removal
Primary Sedimentation Tanks
Fully-Mixed Aerated Lagoon
Secondary Clarifier
Facultative Ponds
Maturation Ponds
Discharge to Environment
Return Activated Sludge
Waste Activated Sludge
Primary Sludge
Heated Aerobic Digesters (ATAD)
To Forest Disposal

Bell's Island WWTP (Municipal plus Major Industries)

Comparisons of Wanganui to Other Aerated Lagoon Treatment Plants Referred to by MWH



Raw Wastewater

Dissolved Air Flotation

Float Solids to Rendering or Composting

Fully-Mixed Activated Sludge Basin

Fully-Mixed Activated Sludge Basin

Secondary Clarifier

UV Disinfection

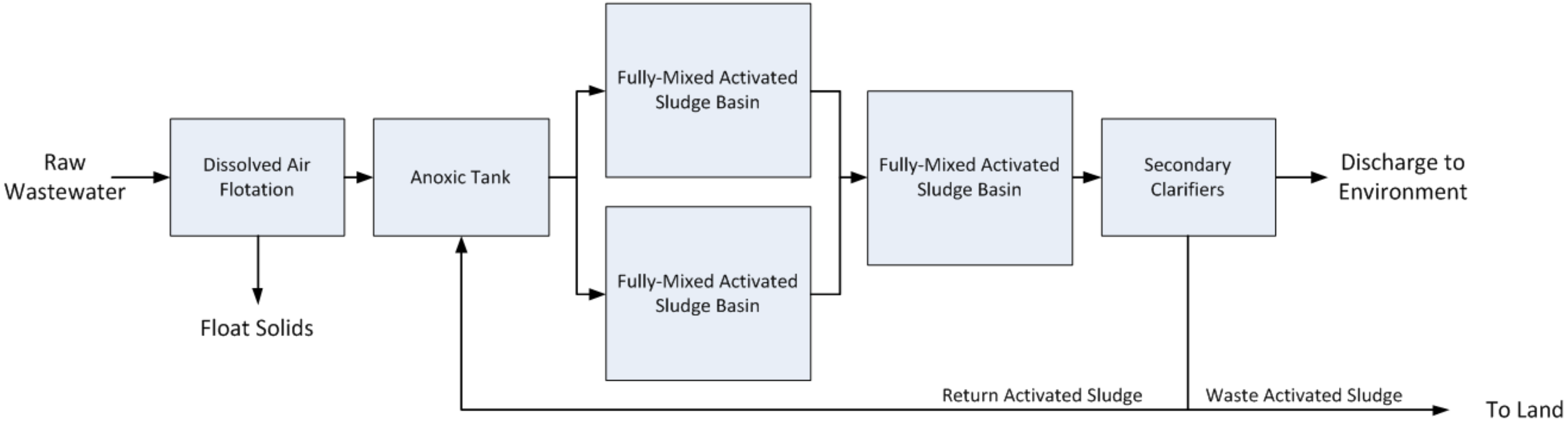
Discharge to Environment

Waste Activated Sludge

Applied to Land

Return Activated Sludge

<u>Alliance Pukeuri WWTP Flow Diagram (Large meat processing plant)</u>



Raw Wastewater

Dissolved Air Flotation

Float Solids

Anoxic Tank

Fully-Mixed Activated Sludge Basin

Fully-Mixed Activated Sludge Basin

Fully-Mixed Activated Sludge Basin

Secondary Clarifiers

Discharge to Environment

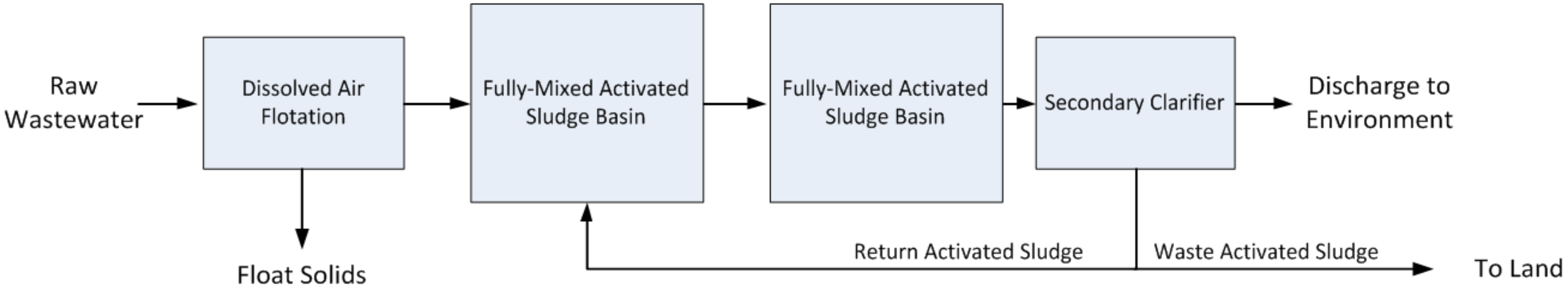
Return Activated Sludge

Waste Activated Sludge

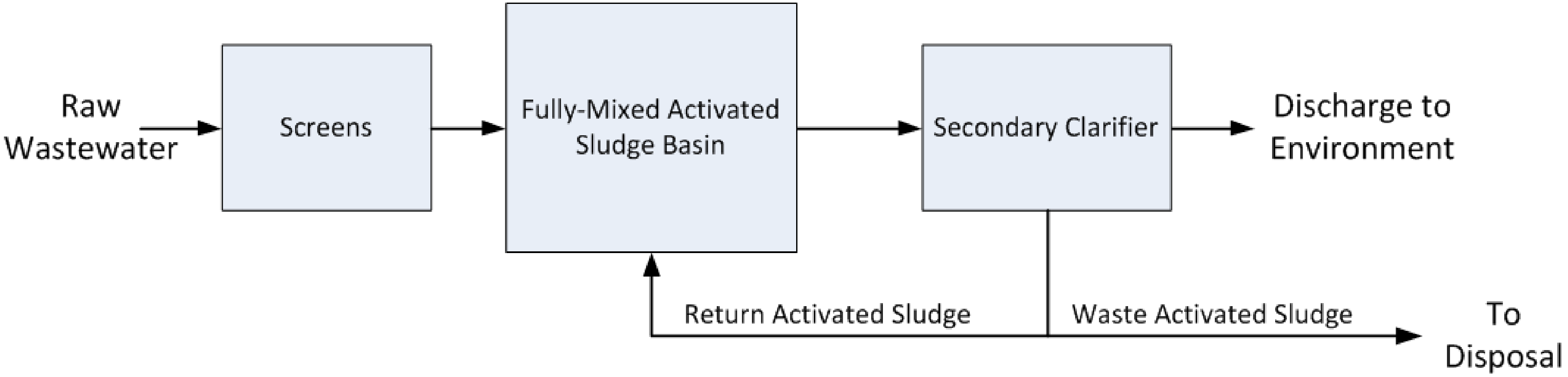
To Land

<u>Fonterra Edendale WWTP Flow Diagram (Dairy Processing)</u>

Comparisons of Wanganui to Other Aerated Lagoon Treatment Plants Referred to by MWH



Fonterra Waitoa WWTP Flow Diagram (Dairy processing)



Open Country Dairy Waharoa WWTP Flow Diagram (Dairy Processing) Waikato

MWH Concept from Report 10 (2003)