Title
Preservation of a Pristine Lake for Future Generations: Llanquihue Lake, X Region, Chile

Authors
Delorenzo, Angela
Colibri, Mariana

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PRESERVATION OF A PRISTINE LAKE FOR FUTURE GENERATIONS

LLANQUIHUE LAKE, X REGION, CHILE.

LA 222 Hydrology for Planners

Term Project Proposal

Angela Delorenzo. Mariana Colibri.

May 3, 2012

Introduction

Study goals and significance

The focus of the project is water quality and clarity in the lake LLanquihue, located at the south of Chile. The approach is through a case study of a small urban area, Puerto Octay, that is projected to expand the existing urban area from a 1,6% to a 18% of the total region area on a period of time of 30 years. The urban expansion plan was recently developed by a Chilean University, and our proposal is to quantify the existing runoff from the urban area (as a main source of pollutants into the lake), and compare with the future runoff from the urban area projected, in order to evaluate the risk that the proposed plan could be to maintain water quality standards and come up with recommendations. Our recommendations will be based on the water quality standards set by CONAMA (National Commission of the Natural Environment) on year 2006, and will mainly be about adequate land use to control runoff. We also included buffer areas for streams that cross this urban area in order to avoid stream erosion that is also an important factor affecting water quality on the lake.

Summary

Conclusions

- Given that the regulations about Water quality set by CONAMA refer mainly to monitoring water quality at the lake but doesn't propose strategies or methods to achieve this goal, there is a need of coming up with strategies and ideas that enables future development on the shoreline of the lake Llanquihue to meet the water regulation standards .
- The urban area expansion would duplicate the runoff into the lake. The existed protected area, denominated areas of risk along streams and wetlands in the shoreline, its not big enough if its seen as a detention area before enters the lake. It needs to be expanded to ensure a detention area that can support the future runoff from the projected urban area.
- There are still opportunities to designate land to be protected from development or intense development so it can keep performing the natural functions and services that provide to the ecosystem, by cleaning water, such as existing wetlands and stream corridors.
- Protecting this areas to ensure water quality if the lake, also ensure landscape value or natural patrimony, supporting the increasing touristic activity in the area and ensuring for future generation the existence of the pristine lake.

Recommendations

- Expand the restricted area so the detention area before the lake its big enough to receive the future runoff. This solution is more realistic would avoid construction of treatment area in the future.
- Use this "restricted" area as a potential public space that would educate about water quality and improve touristic offer and resident's quality of life.

Limitations of the study

- We could not found the area of the whole lake watershed. We found information from different sources that states that the watershed area is very small in comparison with the size of the lake resulting in the shoreline area being the most relevant for water quality impacts. We think it's important to corroborate this information.
- For the purpose of this project, the study was based on the watershed were consolidate urban area is built and were an important part of the expansion of the urban area is projected.
- We are also assuming for the purpose of the study that runoff it's the most relevant source of contamination based on the studies made on Lake Tahoe which we used as precedents for our study and proposal.

Project Context

Context of the problem

Lake Llanquihue is part of an important touristic Lake district area called "Lagos Araucanos" that includes 12 glacial originate lakes between the 30º and 42ª latitude S and 71ª and 72ª longitude W, and at an altitude between 117 to 590 meters over sea level. The watershed soils are mainly from volcanic origin and were mostly covered by "Valdivian" Forest before the watershed was development.

Lake Llanquihue is the biggest lake of this region and the second biggest lake of the country. The shoreline has 196,5km and its surface reaches the 870,5 km2. The mean depth has been estimated to be 187 m, and the lake stores a volume of 158,6 km3 (DGA General Water Agency1987).

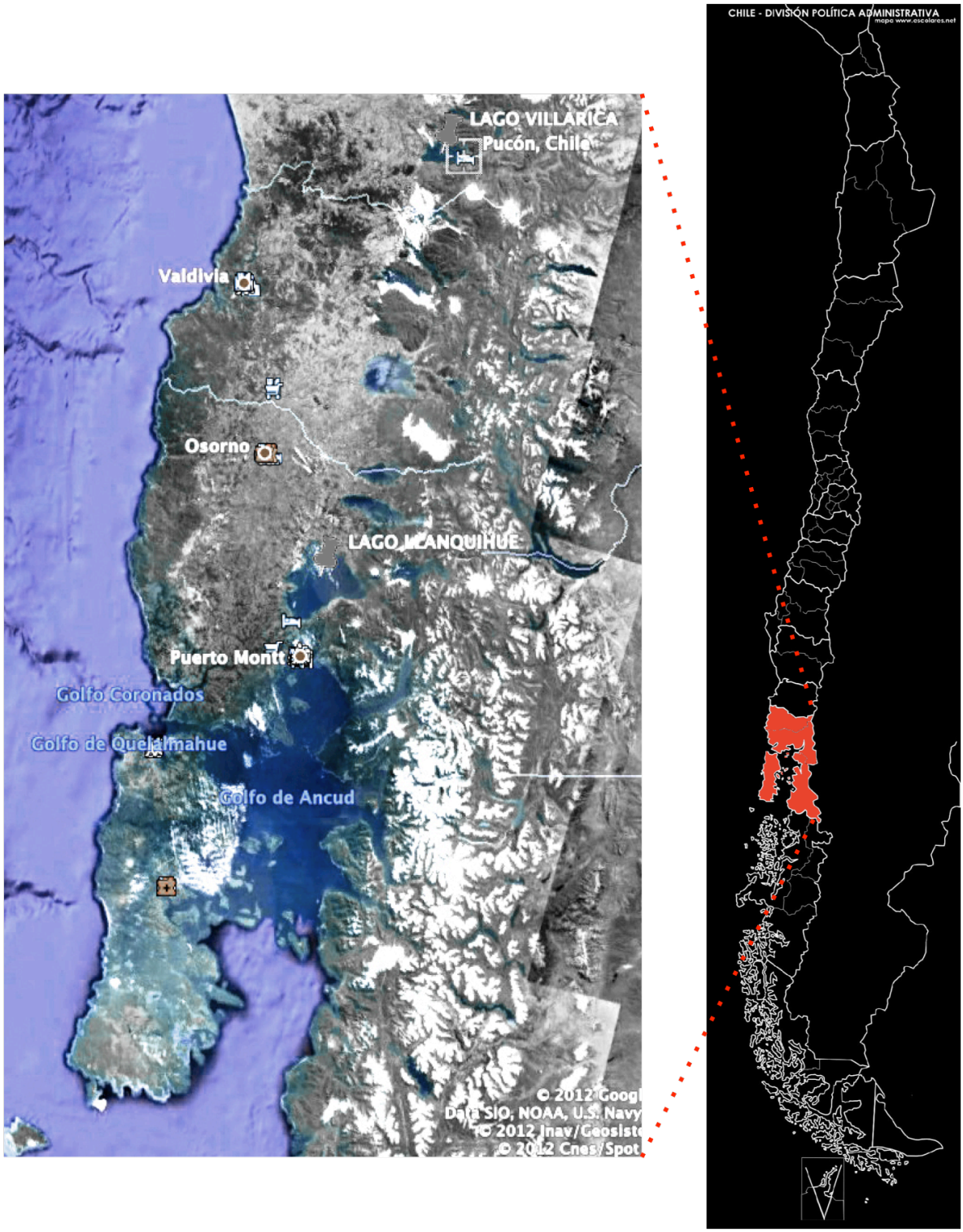
Today, Llanquihue lake presents the shoreline most developed from the 12 lakes considered in the district, has the highest number of salmon cultivation areas, and sustains other important economic activities for the region such as tourism and fly fishing (considered one of the most visited watersheds by the SERNATUR (National Tourism Agency)).

The watershed area is very small in comparison with the lake surface, which directly affects on the renovation period of the water being 74 years, being the main water source rainfall (Soto y Campos, 1995). This fact is believed to be the reason why the lake water quality and clearly has not been that disturbed yet, being the tropic levels still low. Also, its believed that the highest water quality and clarity risks are within the shoreline areas that have direct contact with the lake together with the activities within the lake itself (Soto, 1993).

This acknowledgement and the fact that the shoreline area sustains the main urban areas and future projected urban areas for the next 30 years, evidence the need to create regulations and legal actions I order to preserve the lake. In 2006 the CONAMA (National Environment Commission) through different local agencies and local government finally created a regulation that basically states that the tropic levels must be maintain as the existing conditions through time. The regulation includes monitoring but does not include strategies or action plans to achieve this goal.

*See appendix for information about existing conditions on water quality and clarity of the lake

LLANQUIHUE LAKE
PRESERVING PRISTINE LAKE



Location Map

LLANQUIHUE LAKE
PRESERVING PRISTINE LAKE

Problem Statement

There is an existing need to come up with strategies that enables future development on the shoreline of the lake Llanquihue to reach the new water regulation standards set on 2006 by the CONAMA. And that could be applied to other lakes on the district.

Puerto Octay is one of the four administrative areas on the Llanquihue lake shoreline with 196 km2 being part of it. From the Total area 1,6% is urbanized and recently, a master plan has been proposed for an expansion of the urban area during the next 30 years that would increase the urban area to an 18%.

Most of the urban area watershed drains into the lake, by non-source point runoff. We are assuming for the purpose of these studies that the main pollutants are Oil and Grease from roads and other pervious areas, together with runoff from cultivate lands within the watershed.

The lake has a slow renovation period of water, and today the area available for water being detain before enters the lake is big enough, for what we found on our calculations, but with the urban expansion, the runoff would be duplicated.

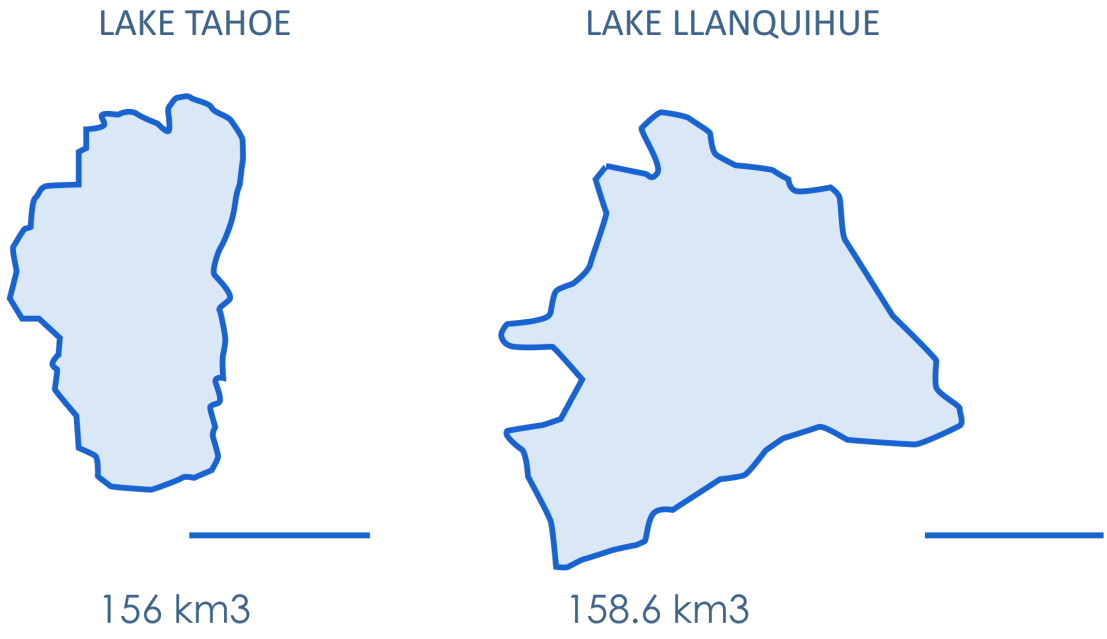
Our primary goals are to:

- Reduce risk of water quality and clarity disturbance by new urban development
- Recommend and area that should be preserve for detention of water runoff from the urban areas that is enough to ensure the water quality and clarity of the lake.
- The area to be protected should be able to connect with the urban area so it becomes a city feature that protects the landscape value and at the are time it's a touristic area.

Methodology

To determine the set of criteria that would inform a land use plan assessment for the existing and proposed expansion urban area of Puerto Octay, we use the following methods:

1. Study the case of Lake Tahoe Water quality and clarity proposal "Keep Tahoe Blue" and Land use Criteria, We used this case study as a precedent to make assumptions about the main pollutant sources and steps to take towards maintaining or improving water quality. Lake Tahoe project helps as understand the different dimensions and impacts of water quality to the region being a touristic area. Llanquihue lake has similar volume and its also and important touristic feature for Chile worth to protect. Setting this precedent strategy, in the future Llanquihue project could become a precedent for the other 11 lakes on the "Araucano" district.



2. Quantify of existing conditions' and future urban expansion plan conditions in relationship with runoff and natural landscape impact, in order to identify potential areas where to protect.

Analysis

1. **Water Quality Approaches Lake Tahoe – Summary and Conclusions**
2. **Puerto Octay Context and RunOff and Detention areas analysis**
3. **Puerto Octay detention area proposal and buffer Stream Corridors Opportunities.**

1. Water Quality Approaches Lake Tahoe – Summary and Conclusions

Summary of the document *"Charting a Course to Clarity"* from the league to Keep Tahoe Blue website.

Content provided by Environmental Incentives, LLC Document production assistance provided by Allegro Communication Consulting.

The Clarity Challenge is a call to reverse the clarity decline and achieve Lake Tahoe clarity of nearly 80 feet by 2025.

How are we going to restore Lake Tahoe's famed clarity?

- **What pollutants are causing Lake Tahoe's clarity loss?**
- **How much of each pollutant is reaching Lake Tahoe?**
- **How much of each pollutant can Lake Tahoe accept and still achieve the clarity standard?**

- **What should be the strategy for reducing pollutant inputs to Lake Tahoe?**

- **How will the strategy be implemented?**

- **How will progress be assessed?**

Slowing the clarity decline is an important step. Reversing the decline will be even bigger.
Achievement of the Clarity Challenge is estimated to require 1.5 billion dollars (in 2008 dollars) in capital improvement costs over the next 20 years.
For PDF versions of technical reports for the Lake Tahoe TMDL visit: www.waterboards.ca.gov/lahontan

Spectacularly blue Lake Tahoe is situated between the crest of the Sierra Nevada mountains on the west and the Carson range on the east, with an average surface elevation of 6,225 feet above sea level. The geologic basin that cradles the lake is dominated by impressive mountains, steep slopes and erosive, nutrient-poor granitic soils as well as volcanic rocks and soils. The lake's montane subalpine watershed is predominantly vegetated by mixed conifer forests that shelter the 63 streams that flow into Lake Tahoe. The lake has one outlet, the Truckee River, which ultimately drains to Pyramid Lake, a terminal lake in Nevada.

The lake holds about 39 trillion gallons of water. It takes roughly 700 years for the average drop of water entering the lake to travel through and out to the Truckee River.

The Lake Tahoe Basin is a summer and winter destination for millions of visitors annually and is home to approximately 60,000 year-round residents. The lake is prized as a recreation venue, with people swimming, fishing, kayaking, skiing and boating in and on its waters.

Lake Tahoe clarity declined at an average rate of approximately nine inches per year between 1968 and 2000. One-third of Lake Tahoe's unique clarity was lost during this period. The Lake Tahoe clarity standard of nearly 100 feet has not been achieved since the standard was adopted in 1975. However, scientific evidence indicates that the trend of decline has slowed since 2000 and can be reversed so that nearly 100 feet of clarity is possible in Lake Tahoe once again Water clarity is measured using a tool called a Secchi disk—a device resembling a dinner plate that is used to measure water transparency in open waters.

The Lake Tahoe transparency standard for Secchi depth—nearly 100 feet—is the annual average Secchi depth measured between 1968 and 1971.

What pollutants are causing Lake Tahoe's clarity loss?

Declining clarity is attributable to both the increase in fine sediment particles and the increase in algae production from inputs of nitrogen and phosphorus.

Fine Sediment Particles

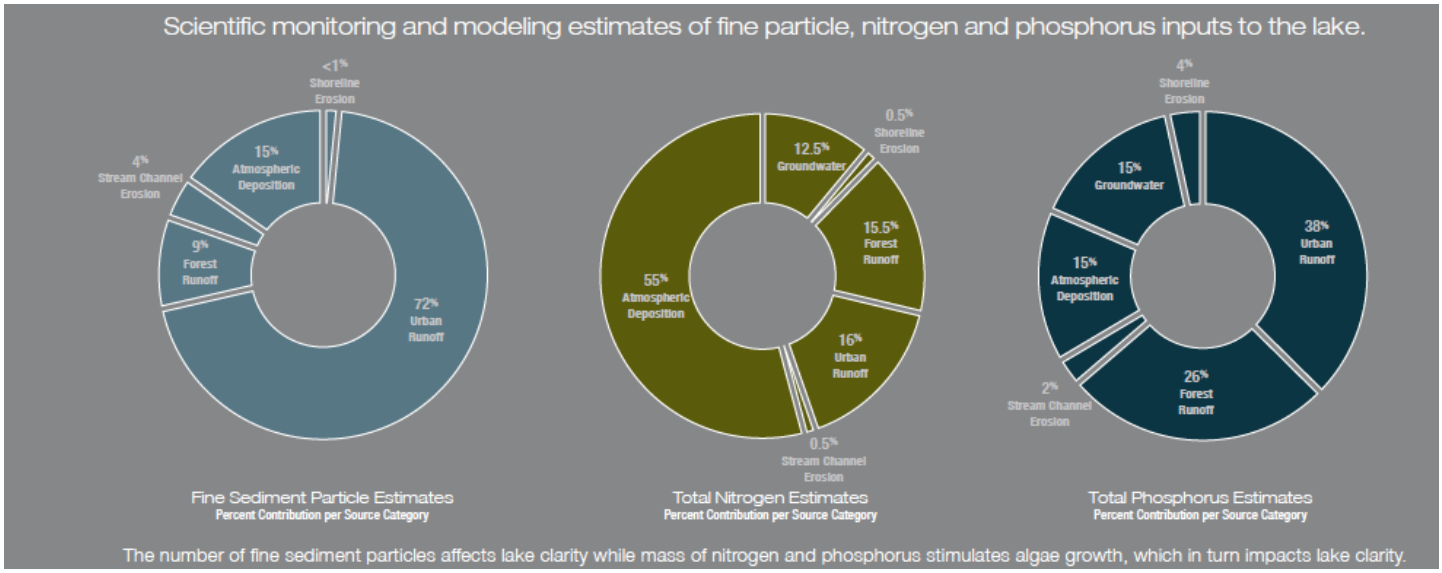
Fine sediment particles originate in the watershed. Soil disturbance, application of road abrasives and other activities mobilize fine sediment particles. These particles are produced in and travel through streams, storm drains, and the air, into the lake.

Algae Production

Algae are water plants with no true leaves or stems. While some algae exist naturally, the amount of algae in the water increases as more nitrogen and phosphorus are added to the lake. Higher amounts of phytoplankton—free floating algae—in the water absorb more light and reduce light penetration into deeper waters. This too diminishes the clarity of the lake. The following graph illustrates how algae production in Lake Tahoe has dramatically increased in recent years.

The accumulation of attached algae on rocks, piers, boats and other hardbottomed substrates is a striking indicator of Lake Tahoe's declining water quality. Thick expanses of periphyton biomass often coat the shoreline in portions of the lake during the spring. Page 15

Most of the pollutants reaching Lake Tahoe come from four pollutant sources-urban runoff, forest runoff, stream channel erosion and atmospheric deposition. Estimates of the amount of each pollutant entering the lake from each pollutant source are derived from scientific monitoring and modeling.



An approximate 32% reduction (from 2004 levels) in fine sediment particles is needed to reach the Clarity Challenge, about 80 feet, in the next 20 years. An approximate 65% reduction (from 2004 levels) in fine sediment particles is needed to reach the clarity standard at nearly 100 feet. Reductions of nitrogen and phosphorus (not portrayed in this graphic) accompanying the fine sediment particle reductions are also needed to reach these clarity goals.

What should be the strategy for reducing pollutant inputs to Lake Tahoe?

The strategy for improving lake clarity emphasizes reducing fine sediment particles originating in urban areas that are transported to the lake through stormwater runoff and atmospheric deposition. The strategy also includes efforts to reduce pollutants originating in, and transporting through, forests and stream channels. The cost of strategy implementation over a twenty-year period (in 2008 dollars) is estimated at $1.5 billion.

Urban runoff

The strategy employs area-wide stormwater treatment and erosion control projects such as: road vacuum sweeping, wetland and passive filtration basins, media filters in stormwater vaults, private property BMP implementation, and intensive maintenance of stormwater infrastructure.
One element of the strategy is to investigate further how, when and where to apply these technologies for the best results. To meet the Clarity Challenge, fine sediment particles from urban runoff need to be reduced by 34% from 2004 levels. To meet the clarity standard, fine sediment particles from urban runoff need to be reduced by approximately 71% from 2004 levels.
Atmospheric deposition – technology

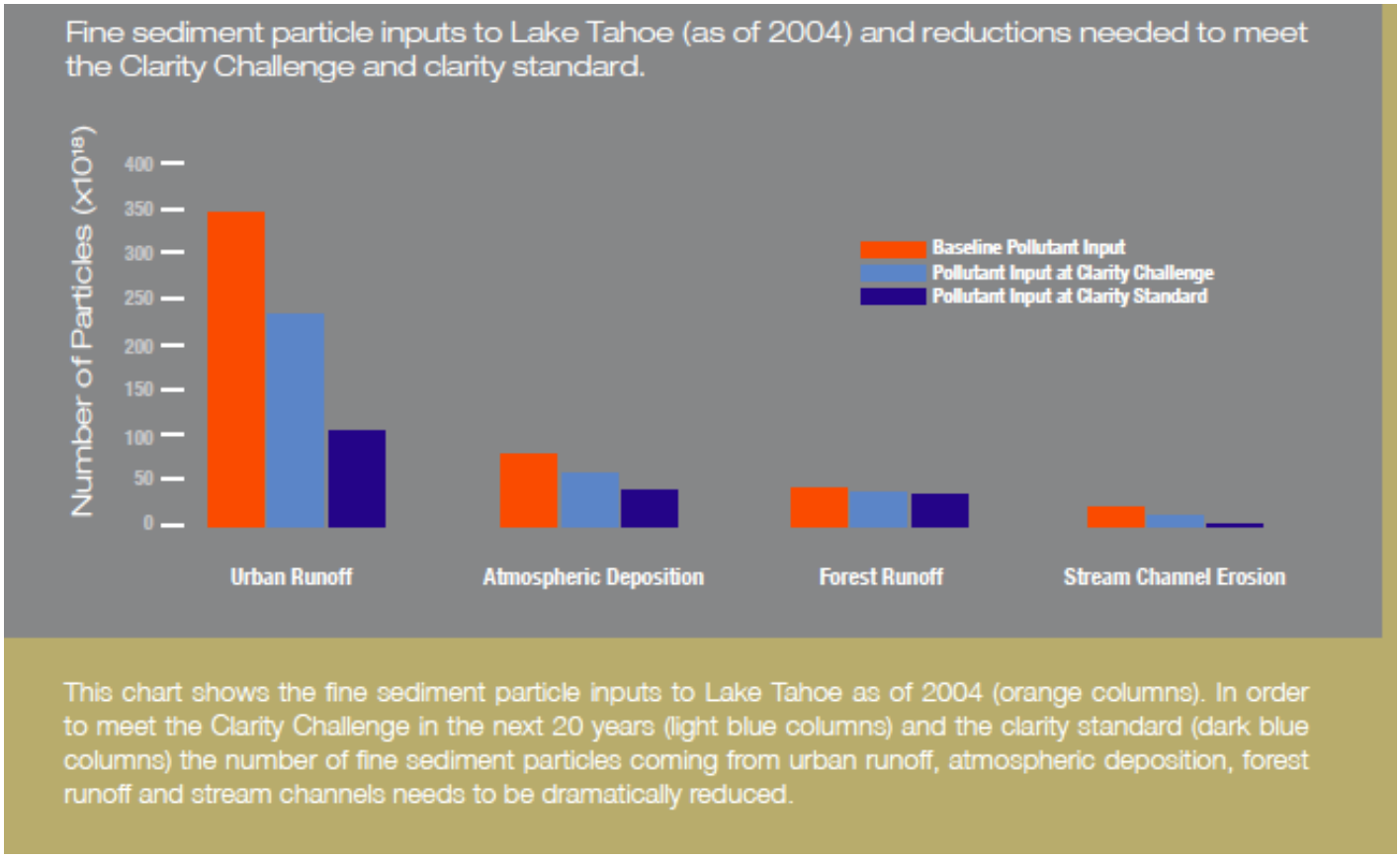
Forest runoff

The strategy calls for control of runoff from forest sources to reduce pollutants to the lake. Disturbed areas of the forest such as unpaved roads, ski runs and campgrounds yield high amounts of fine sediment particles when compared to the undisturbed forest

Clarity Challenge in 20 years, fine sediment particles from forest runoff need to be reduced by 12% from 2004 levels. To meet the clarity standard, fine sediment particles from forest runoff need to be reduced by approximately 20% from 2004 levels.

Stream channel erosion

Restoring streams reduces pollutant inputs from failing stream banks and eroding stream beds, but more significantly, enhances riparian habitat and improves floodplain function. Further, reconnecting disturbed rivers and streams with the natural floodplain allows the stream system to serve as a natural filter for pollutants coming from the upland areas. In order to meet the Clarity Challenge in 20 years, it is estimated that fine sediment particles from stream channels need to be reduced by approximately 53% from 2004 levels. To meet the clarity standard, it is estimated that fine sediment particles from stream channels need to be reduced by approximately 89% from 2004 levels.



The TMDL strategy is built on a foundation of science. Decades of data collection, work of hundreds of scientists and practitioners, and the findings and projections of scientific models all inform the framework of the strategy. Public opinion also figures significantly in the strategy that the Lahontan Water Board and NDEP have developed. Multiple strategies for meeting the Clarity Challenge were discussed with a forum of well-informed members of the public (stakeholders) who informed the selection of strategy elements.The strategy was developed through a cyclic process of design and adjustment in which scientists and engineers, stakeholders, and TMDL staff and consultants participated.

There were three cycles in the process:

The objective of each was to: **(1) Identify, screen and analyze opportunities to control pollutants; (2) Formulate strategies integrating opportunities to control pollutants from all pollutant sources; (3) Develop and refine a recommended strategy for consideration by the Lahontan Water Board and NDEP.**

During each cycle in development:

- An interim product (containing draft strategy elements) was developed to engage people in substantive discussion and review;
- Stakeholders commented on the interim product;
- Product was adjusted to address comments—resulting in a new interim product;
- Additional stakeholder questions were answered.

How will the strategy be implemented?

A pollutant reduction tracking system and regional stormwater monitoring program will inform the adaptive management of the Lake Tahoe TMDL

Conclusions

Based on the Tahoe Water Quality program, we set the same questions to Lake Llanquihue and in our next analysis we focus on finding the relevant information and data that would enable us to answer this questions. Some of these questions still withought answer, which make this project a work in progress.

How are we going to preserve Lake LLanquihue famed clarity?

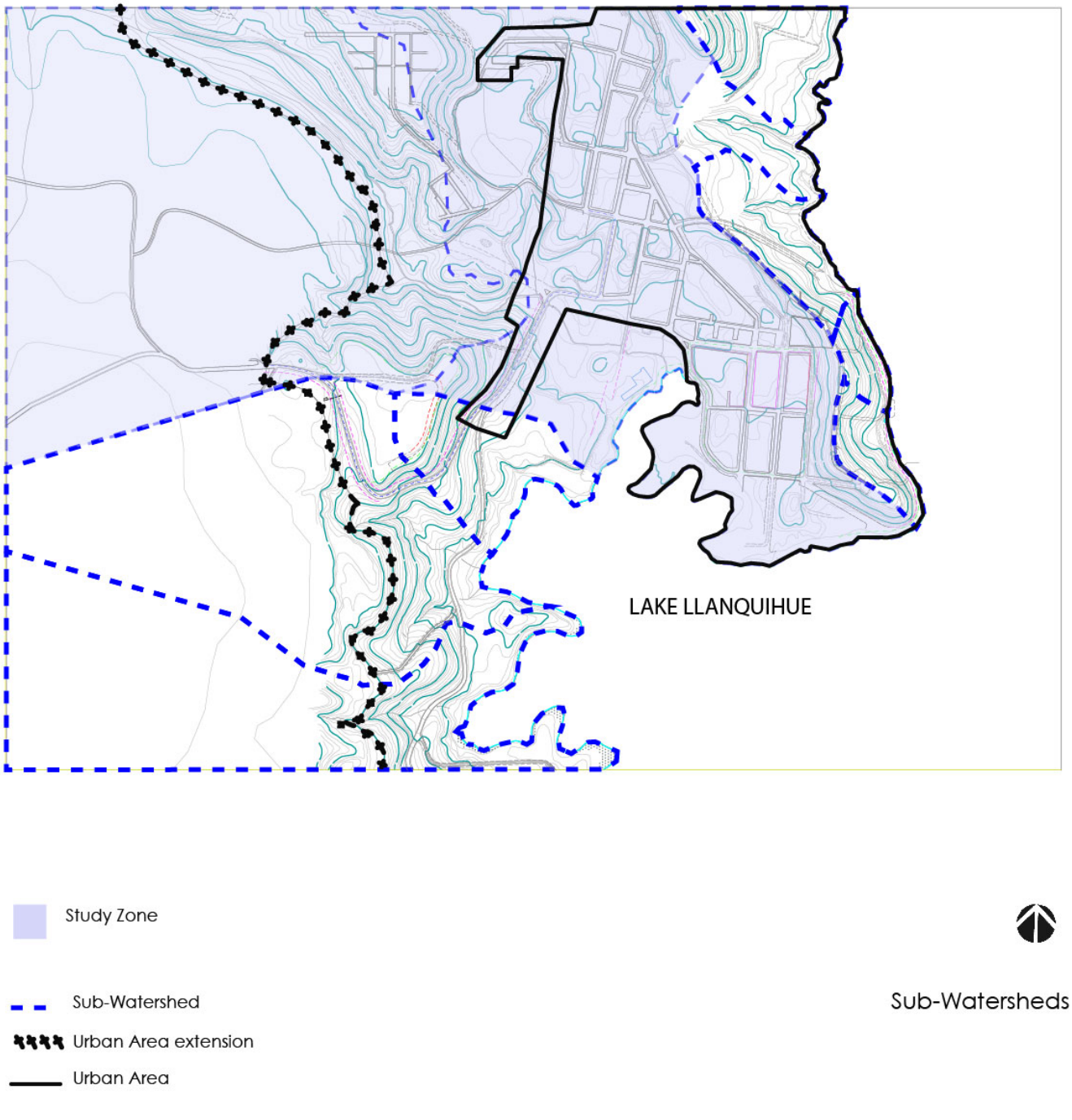
- What pollutants are causing Lake LLanquihue clarity loss?

- How much of each pollutant is reaching Lake LLanquihue?
- How much of each pollutant can Lake LLanquiue accept and still achieve the clarity standard?
- **What should be the strategy for reducing pollutant inputs to Lake Llanquihue?**
- How will the strategy be implemented?
- How will progress be assessed?

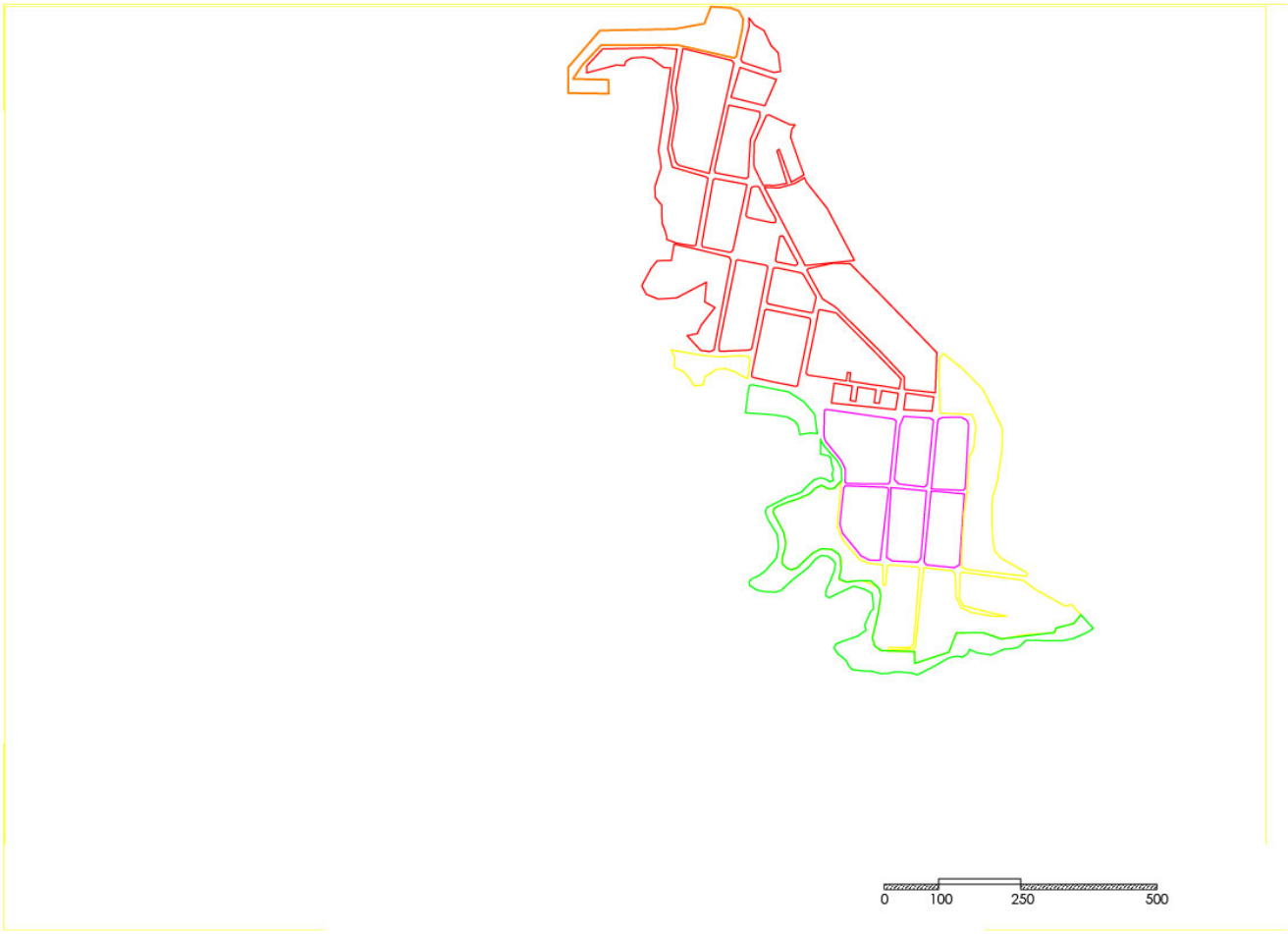
2. Puerto Octay Context and water quality analysis

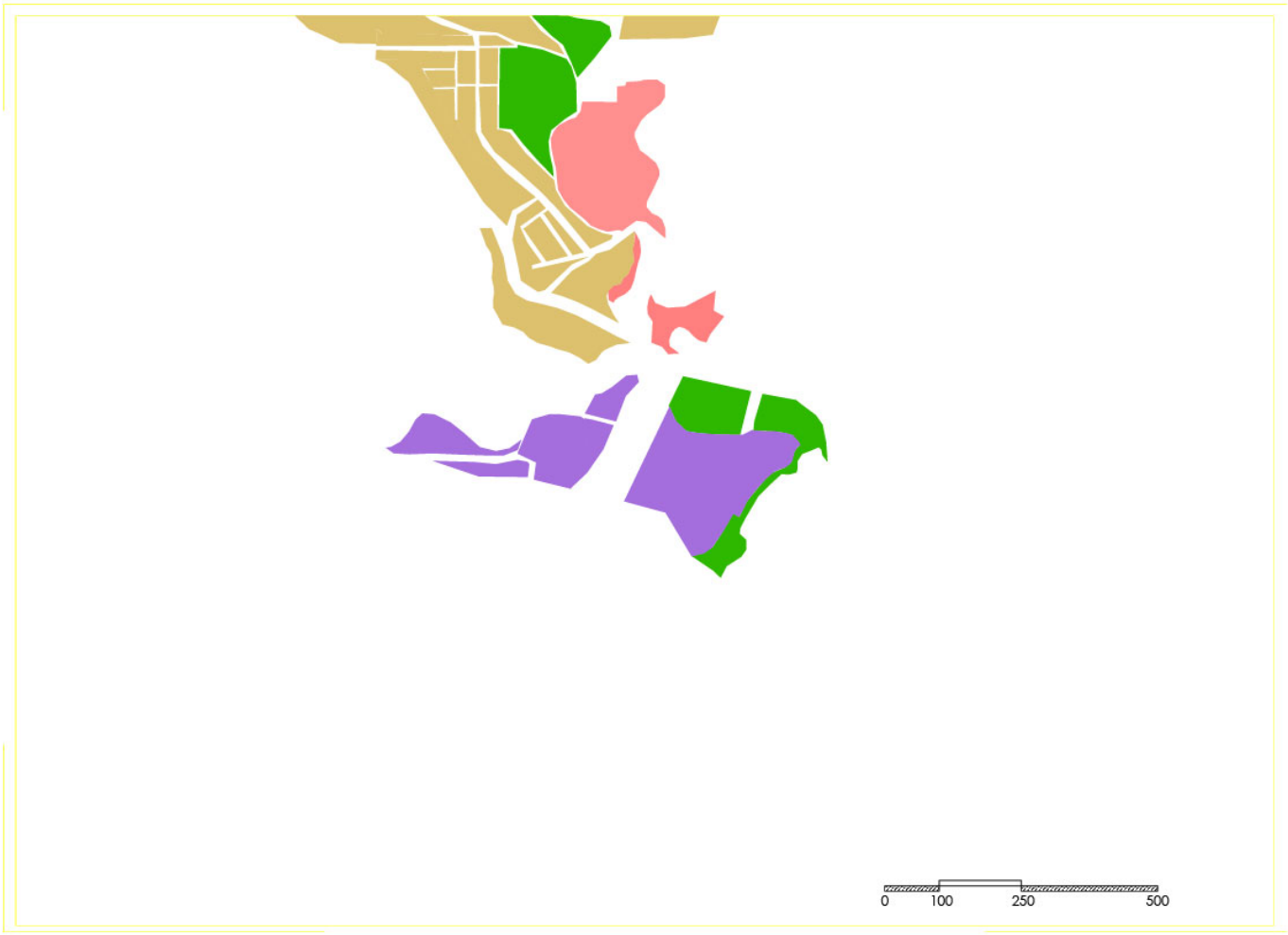
- **How much of each pollutant can Lake LLanquihue accept and still achieve the clarity standard?**

Our first analysis was identifying the Watershed are of study, and the urban area and urban expansion area within this watershed.



We identify each zone type on the regulatory plan within these two areas and we assign C values give by different papers we were able to find from Chilean papers.





ZE 2

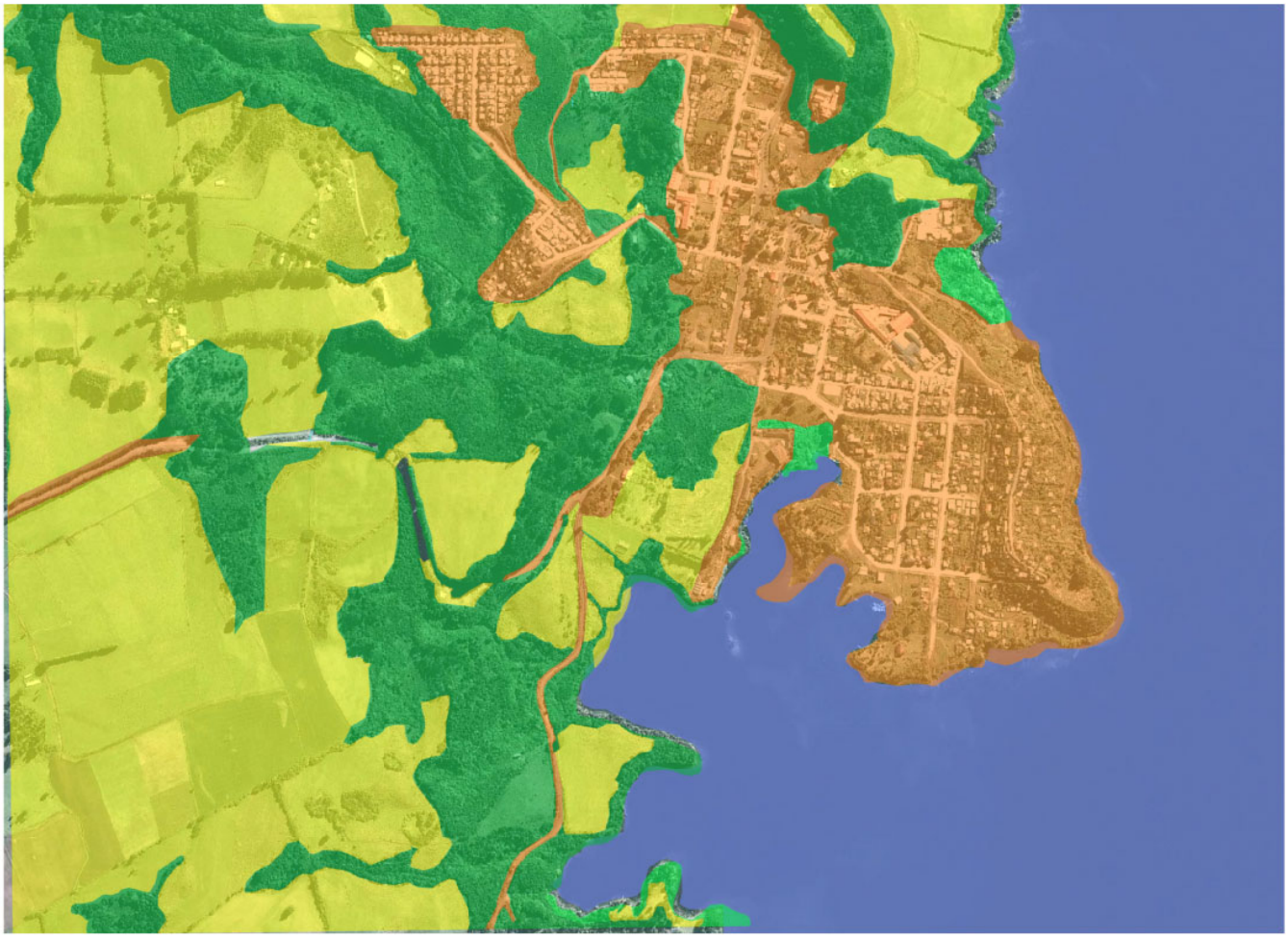
ZE 3

ZE 4

Z Risk

Urban Expantion Zones

To be able to assign a value to the areas that are not still developed and that are part of the urban expansion area plan, we produced an existing vegetation map based on a Google earth image, and we assigned C values to each of these still undeveloped areas.

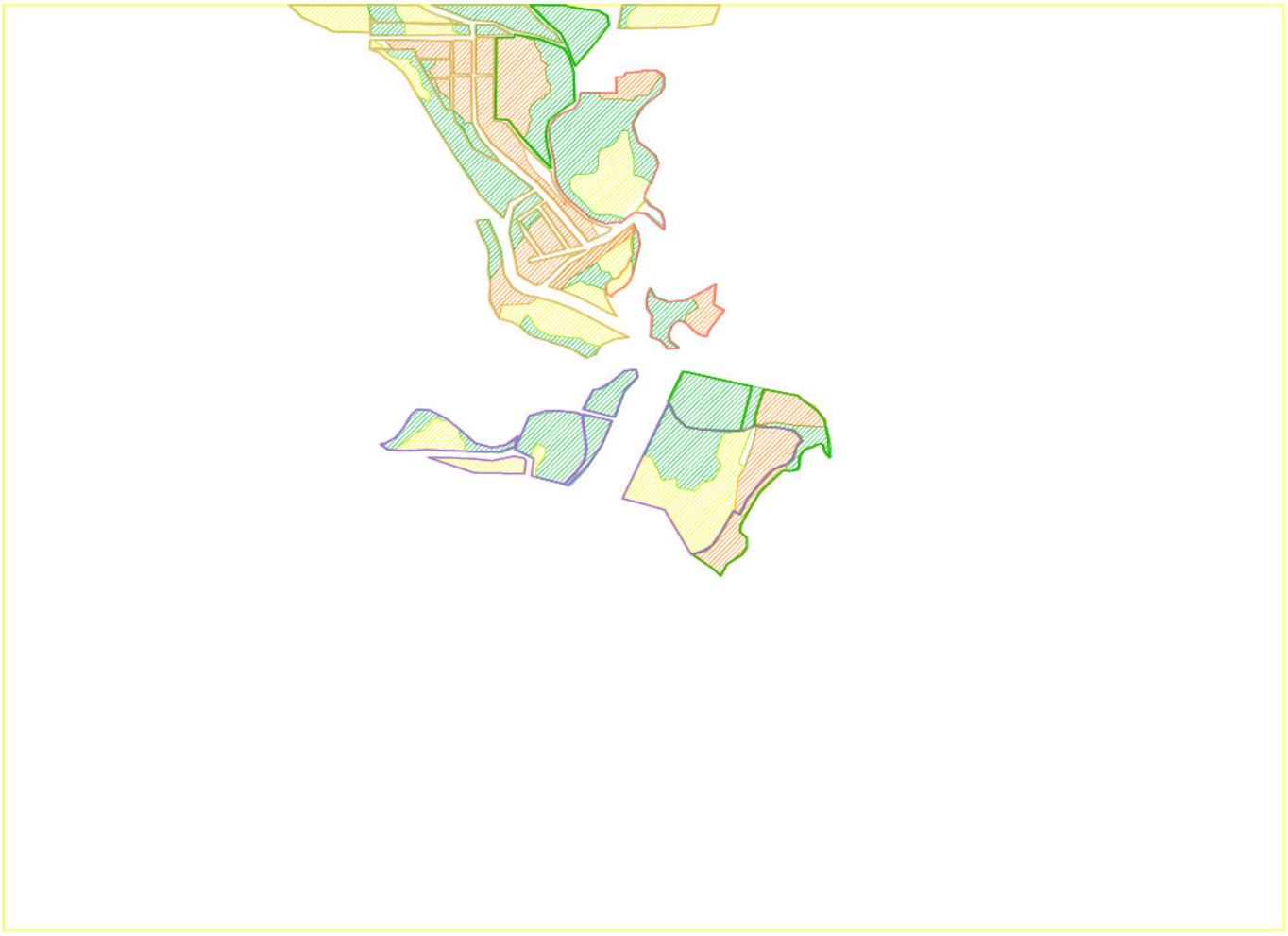


Native Vegetation

Agricultural/Farming

Invasive Vegetation

Vegetation

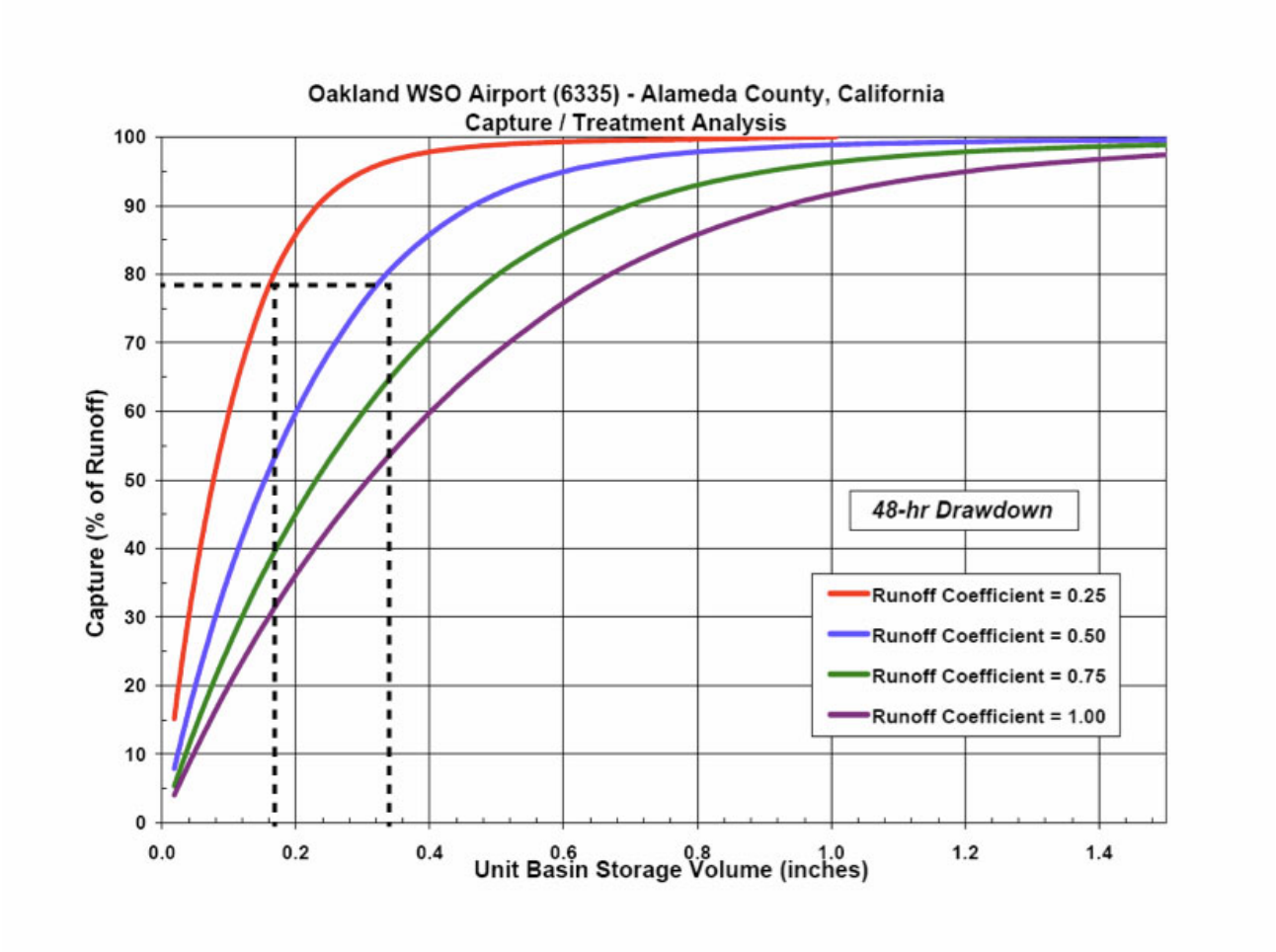


ZE 2
ZE 3
ZE 4
Z Risk

Native Vegetation
Agricultural/Farming
Invasive Vegetation

Urban Expansion Zones + Vegetation

We used the following chart to estimate a unit volume that would permit as calculate and area for detention pond. Using C 0.25 for undeveloped land calculations and C 0.5 for developed areas calculations (the density of the built area is low).



Urban Area Calculations Summary

DETENTION BASIN UNIT VOLUME	0,35	INCH
	0,029	FEET

URBAN AREA			
TOTAL RUNOFF		**309,30**	
TOTAL AREA	**123,7**		
TOTAL AREA DET BASIN		**3,59**	**ACRE/FEET**
		3700	CUBIC METER
		12333,3	M2 POR 30 CM HIGH

EXPANSION Urban Area Calculations Summary BEFORE DEVELOPMENT

DETENTION BASIN UNIT VOLUME	0,15	INCH
	0,0125	FEET

URBAN EXPANSION BEFORE DEVELOPMENT			
TOTAL RUNOFF		**0,00**	
TOTAL AREA		**0,00**	
TOTAL AREA DET BASIN		**0,00**	**ACRE/FEET**
		1233	CUBIC METER
		4110,0	M2 POR 30 CM HIGH

EXPANSION Urban Area Calculations Summary AFTER DEVELOPMENT

DETENTION BASIN UNIT VOLUME	0,35	INCH
	0,029	FEET

URBAN EXPANSION AFTER DEVELOPMENT		
TOTAL RUNOFF	**124,90**	
TOTAL AREA	**72,23**	
TOTAL AREA DET BASIN	**2,09**	**ACRE/FEET**
	2466	CUBIC METER
	8220,0	M2 POR 30 CM HIGH

What should be the strategy for reducing pollutant inputs to Lake Llanquihue?

We considered the wetland areas existing o the shoreline of Puerto Octay as areas that are natural "detention ponds". So our evaluation is if this areas, which part of them are protected by the regulatory city plan, are enough on size to treat the existing runoff. With this same criteria we would evaluate the future runoff from the proposed urban expansion area and see if then the wetland areas are enough as detention ponds.

The detention ponds or existing wetland areas were considered with a depth of 30cm to obtain a square meter surface needed.

Conclusions

The existing urban area runoff is covered by the existing wetland areas protected by the city, but with the future urban expansion, more protected space that provide this service will be needed. The Total areas in addition needed are 0,9 Acre/ Feet.

TOTAL AREA DET BASIN	**0,90**	**ACRE/FEET**
	1233	CUBIC METER
	4110,0	M2 POR 30 CM HIGH

There are still opportunities to designate land to be protected from development or intense development so it can keep performing the natural functions and services that provide to the ecosystem, by cleaning water, such as existing wetlands and stream corridors. Protecting this areas to ensure water quality if the lake, also ensure landscape value or natural patrimony, supporting the increasing touristic activity in the area and ensuring for future generation the existence of the pristine lake.

Corporative Touristic image from Puerto Octay city county

Appendices

1. Data for calculation for Puerto Octay

CONSOLIDATE URBAN AREA BY ZONES

Zone	Area mts	Area acres	C	i	Q
Z2	**15410**	**3,8**	**0,5**	**4,2**	**8,00**
Z1 POLIGON	2844,3	0,7	0,5	4,2	1,48
Z1	4157,8	1,0	0,5	4,2	2,16
	17783,6	4,4	0,8	4,2	14,77
	18661,2	4,6	0,5	4,2	9,68
	3811,2	0,9	0,5	4,2	1,98
	7502	1,9	0,5	4,2	3,89
	7981,1	2,0	0,5	4,2	4,14
	2228,7	0,6	0,5	4,2	1,16
	8310,4	2,1	0,5	4,2	4,31
	13871,1	3,4	0,5	4,2	7,20
	1270,5	0,3	0,5	4,2	0,66
	14692,4	3,6	0,5	4,2	7,62
	10187,7	2,5	0,5	4,2	5,29
	4272,3	1,1	0,5	4,2	2,22
	22267,2	5,5	0,5	4,2	11,55
	11435,5	2,8	0,5	4,2	5,93
	141103,4	34,9	0,8	4,2	117,15
	3608,1	0,9	0,5	4,2	1,87
	1525,8	0,4	0,5	4,2	0,79
Z1 TOTAL	**294670**	**72,8**		**4,2**	**203,86**
AREA ROADS/PLAZA	**39873,2**	**9,85**	**0,9**	**4,2**	**37,24**
PLAZA	**3491**	**0,9**	**0,12**	**4,2**	**0,43**
Z3	8258,4	2,0		4,2	
	13226,6	3,3		4,2	
	5132,2	1,3		4,2	
	58018,3	14,3		4,2	

	24468,4	6,0		4,2	
Z3 TOTAL	**109103,9**	**27,0**	**0,5**	**4,2**	**56,62**
ZR	5070,2	1,3		4,2	
	6386,4	1,6		4,2	
	26489	6,5		4,2	
ZR TOTAL	**37945,6**	**9,4**	**0,08**	**4,2**	**3,15**

TOTAL RUNOFF		**309,30**	
TOTAL AREA	**123,7**		
TOTAL AREA DET BASIN		**3,59**	**ACRE/FEET**
		3700	CUBIC METER
		12333,3	M2 POR 30 CM HIGH

EXTENSION URBAN AREA
BEFORE DEVELOPMENT

ZONE	NATIVE mt	Native Acre	C	i	Q	CULTIVO mt	Cultivi Acre	C	i	Q	VEG. 50% mt	Veg 50% Acre	C	i	Q
ZE2	6405,6					5681,2					2906				
	5681,2					2372,2					2078,7				
	2369,6					1890,4					2250,2				
	1514					6509,4					1085,1				
	522					2913					716,1				
	925,2					2406,3					2624,8				
	295,5					9540,4					9161,6				
	14052										2116,1				
	495,2										3253,5				
	640,4										4300,8				
	1716,3										2558,4				
	2338,7										1512,5				
	570,6										3375,2				
	2780,6														
	2062,4														
	674,5														
ZE2 TOTAL	**43043,8**	**10,64**	**0,05**	**4,2**	**2,233634457**	31312,9	**7,74**	**0,184**	**4,2**	**5,979606502**	37939	**9,37**	**0,1**	4,2	**3,937471025**
ZE3	2766,6					21133,7					8836				
	3640,1														

	16763,4														
	3964,7														
	13315,4														
	856,4														
ZE3 TOTA	41306,6	10,21	0,05	4,2	2,143487449	21133,7	5,22	0,184	4,2	4,035755549	8836	2,18	0,1	4,2	0,917037718
ZE4	22265					1322,6					3672,3				
	4672					13044,7					3591,1				
ZE4 TOTA	26937	6,66	0,05	4,2	1,3978183	14367,3	3,55	0,184	4,2	2,743623251	7263,4	1,79	0,1	4,2	0,753826591
Zrext.	7579,3										12972,5				
	9979,7										5789				
	14087,3										6543				
	3213														
Zrext. TOTAL	34859,3	8,61	0,05	4,2	1,808923332	0	0	0,184	4,2	0	25304,5	6,25	0,1	4,2	2,626208797

URBAN EXPANSION BEFORE DEVELOPMENT		
TOTAL RUNOFF	**0,00**	
TOTAL AREA	**0,00**	
TOTAL AREA DET BASIN	**0,00**	**ACRE/FEET**
	1233	CUBIC METER
	4110,0	M2 POR 30 CM HIGH

URBAN EXPANSION AFTER DEVELOPMENT

ZONE	NATIVE mt	Native Acre	C	i	Q	Cultivated mt	Cultivi Acre	C	i	Q	VEG. 50% den mt	Veg 50% den Acre	C	i	Q
ZE2	6405,6					5681,2					2906				
	5681,2					2372,2					2078,7				
	2369,6					1890,4					2250,2				
	1514					6509,4					1085,1				
	522					2913					716,1				
	925,2					2406,3					2624,8				
	295,5					9540,4					9161,6				
	14052										2116,1				
	495,2										3253,5				
	640,4										4300,8				
	1716,3										2558,4				
	2338,7										1512,5				
	570,6										3375,2				
	2780,6														
	2062,4														
	674,5														
ZE2 TOTAL	43043,8	**10,64**	**0,5**	**4,2**	**22,33634457**	31312,9	**7,74**	**0,5**	**4,2**	**16,24893071**	37939	**9,37**	**0,5**	4,2	**19,68735512**
ZE3	2766,6					21133,7					8836				
	3640,1														
	16763,4														
	3964,7														
	13315,4														
	856,4														

ZE3 TOTA	4130 6,6	**10,21**	**0,5**	**4,2**	**21,434 87449**	21133,7	**5,22**	**0,5**	**4,2**	**10,966 72704**	8836	**2,18**	**0,5**	4,2	**4,5851 88589**
ZE4	22265 4672					1322,6 13044,7					3672,3 3591,1				
ZE4 TOTA	26937	**6,66**	**0,5**	**4,2**	**13,978 183**	14367,3	**3,55**	**0,5**	**4,2**	**7,4554 97965**	7263,4	**1,79**	**0,5**	4,2	**3,7691 32956**
Zrext.	7579,3 9979,7 14087,3 3213										12972,5 5789 6543				
Zrext. TOTAL	34859,3	**8,61**	**0,05**	**4,2**	**1,8089 2332**	0	**0**	**0,1 84**	**4,2**	**0**	25304,5	**6,25**	**0,1**	4,2	**2,6262 08797**
TOTAL Q PER ZONES		**36,11**			**59,56**		**16,51**			**34,67**		**19,61**			**30,67**

URBAN EXPANSION AFTER DEVELOPMENT		
TOTAL RUNOFF	**124,90**	
TOTAL AREA	**72,23**	
TOTAL AREA DET BASIN	**2,09**	**ACRE/FEET**
	2466	CUBIC METER
	8220,0	M2 POR 30 CM HIGH

OTHER CALCULATIONS

		15%	elev 15%	85%	elev 85%
Distance 1 (urban area)	878	131,7	58	746,3	82
Distance 2 (Along main stream, Urb Ext)	1699,8	254,97	58	1444,83	69

SLOPE

DISTANCE 2		
DISTA PIOINT 1	1189,86	
DISTANCE POINT 2	254,97	
%	0,214285714	21%
DISTANCE 1		
DISTA PIOINT 1	614,6	
DISTANCE POINT 2	131,7	
%	0,214285714	21%

1. Data for runoff calculation and Water quality data for Llanquihue lake

Water quality and transparency chart

Lakes	N NO3 (ug/L)	P Total (ug/L)	Transparency Disc Secchi (m)
Rinihue	127.5	18.0	12
Llanquihue	**340**	**7.4**	**10**
Caburga	113.1	8.5	6.6
Puyehue	--	6.25	9.75
Ranco	58.5	8.0	10.5
Rupanco	21	6.0	10.25
Todos los Santos	142.5	2.8	11.6

RunOff coefficients

For new roads:

Factors	Extreme	High	Normal	Low
Steepness	0.28 – 0.35 Steep over 30%	0.20 – 0.28 Between 10% and 30% steep	0.08 – 0.14 Between 5% and 10% steep	0.08 – 0.14 Less than 5% steep
Infiltration	0.12 - 0.16 Rocks or clay with low infiltration capacity	0.08 – 0.12 Clay soils or silty with low infiltration capacity	0.06 – 0.08 Regular to good infiltratio capacity. 50% of the ares with grasslands or forrest, and no more than 50% cultivated	0.04 – 0.06 Good to exelent infiltration; 90% grasslands or forest or equivalent cover.
Vegetation cover	0.12 - 0.16 Low cover or no vegetation	0.08 – 0.12 Low vegetaion cover or cultivated, less that 20% cover.	0.06 – 0.08 50% of the area covered with grasslands or forest, and no more than 50% cultivated	0.04 – 0.06 Good to excellent infiltration; 90% grasslands or forest or equivalent cover.
Superficial storing	0.10 – 0.12 Not relevant surface depressions, withought humid	0.08 – 0.10 Small amount of surface water well defined, withought humid	0.06 – 0.08 Normal, storage capacity, humid areas with wetlands, lakes	0.04 – 0.06 High capacity of hydrographic system, humid areas with

	areas	areas	or similar	wetlands, lakes or similar

For urban areas

Factors	C
Roofs	0.8
Zincalum Roofs	0,9
Streets and Alleys	0.87
Green Areas	0.12
Gardens or patios with no vegetation cover	0.35
Comercial	0.5

Rainfall intensity charts

Tabla 5: Precipitación según duración y período de retorno Puerto Montt

Duración en horas	Período de retorno en años					
	2	5	10	20	50	100
1	9,8 mm	12,1 mm	13,6 mm	14,9 mm	16,5 mm	17,8 mm
2	13,7 mm	17,0 mm	19,1 mm	21,0 mm	23,2 mm	25,0 mm
4	20,6 mm	25,5 mm	28,6 mm	31,4 mm	34,7 mm	37,5 mm
6	27,6 mm	34,2 mm	38,3 mm	42,1 mm	46,6 mm	50,3 mm
8	32,0 mm	39,7 mm	44,5 mm	48,9 mm	54,0 mm	58,4 mm
10	35,9 mm	44,6 mm	50,0 mm	54,9 mm	60,7 mm	65,6 mm
12	39,8 mm	49,4 mm	55,4 mm	60,8 mm	67,3 mm	72,6 mm
14	43,3 mm	53,8 mm	60,2 mm	66,1 mm	73,1 mm	79,0 mm
18	50,7 mm	63,0 mm	70,5 mm	77,5 mm	85,7 mm	92,5 mm
24	58,9 mm	73,1 mm	81,9 mm	90,0 mm	99,5 mm	107,5 mm

Del cuadro anterior se puede determinar la curva Intensidad – Duración – Frecuencia:

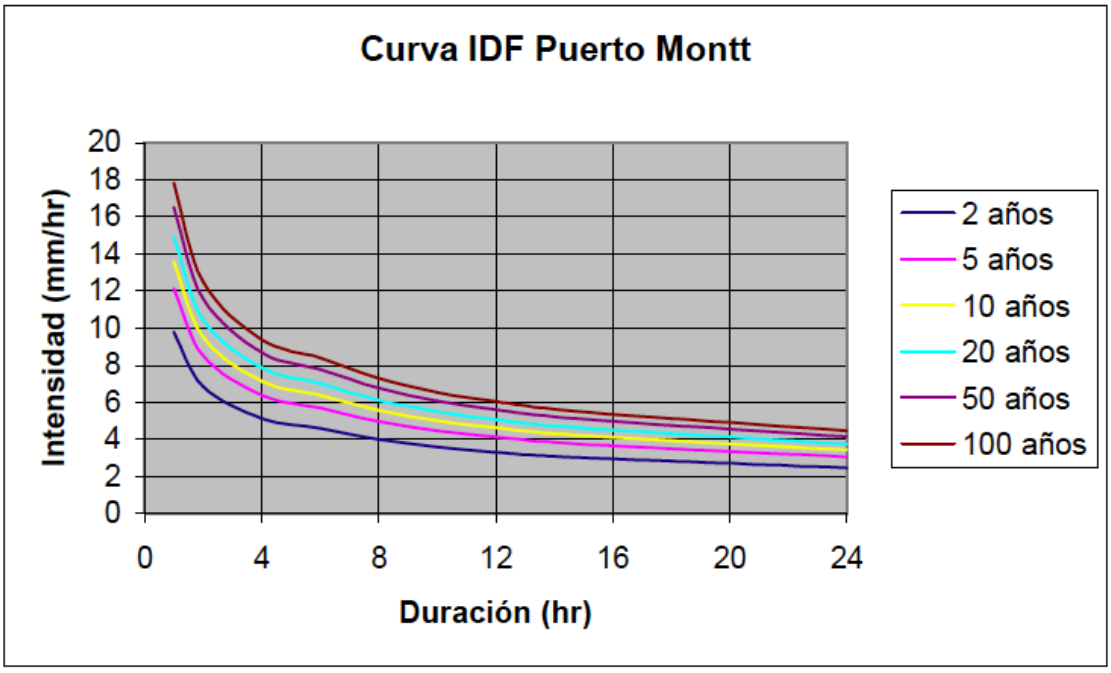
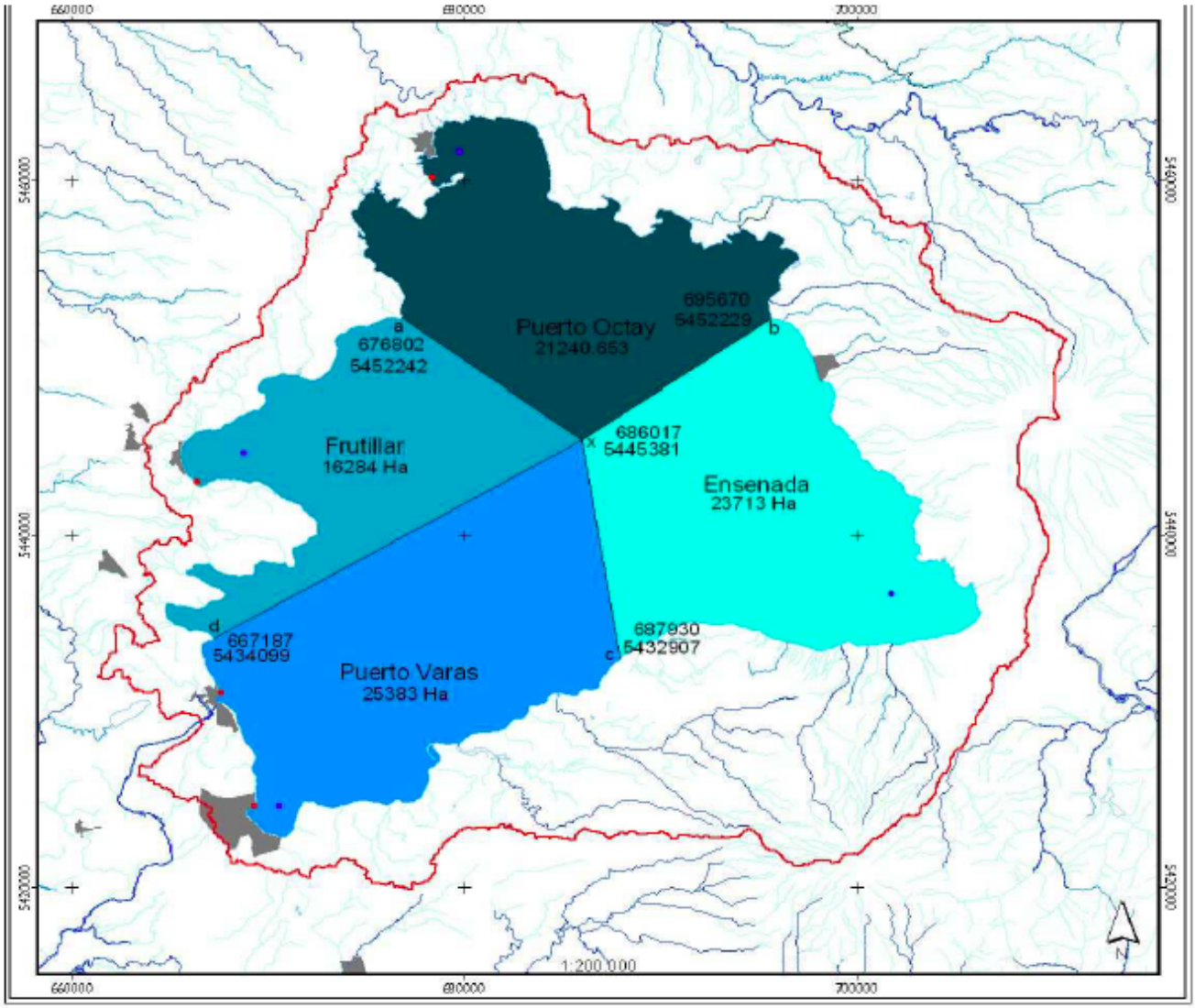


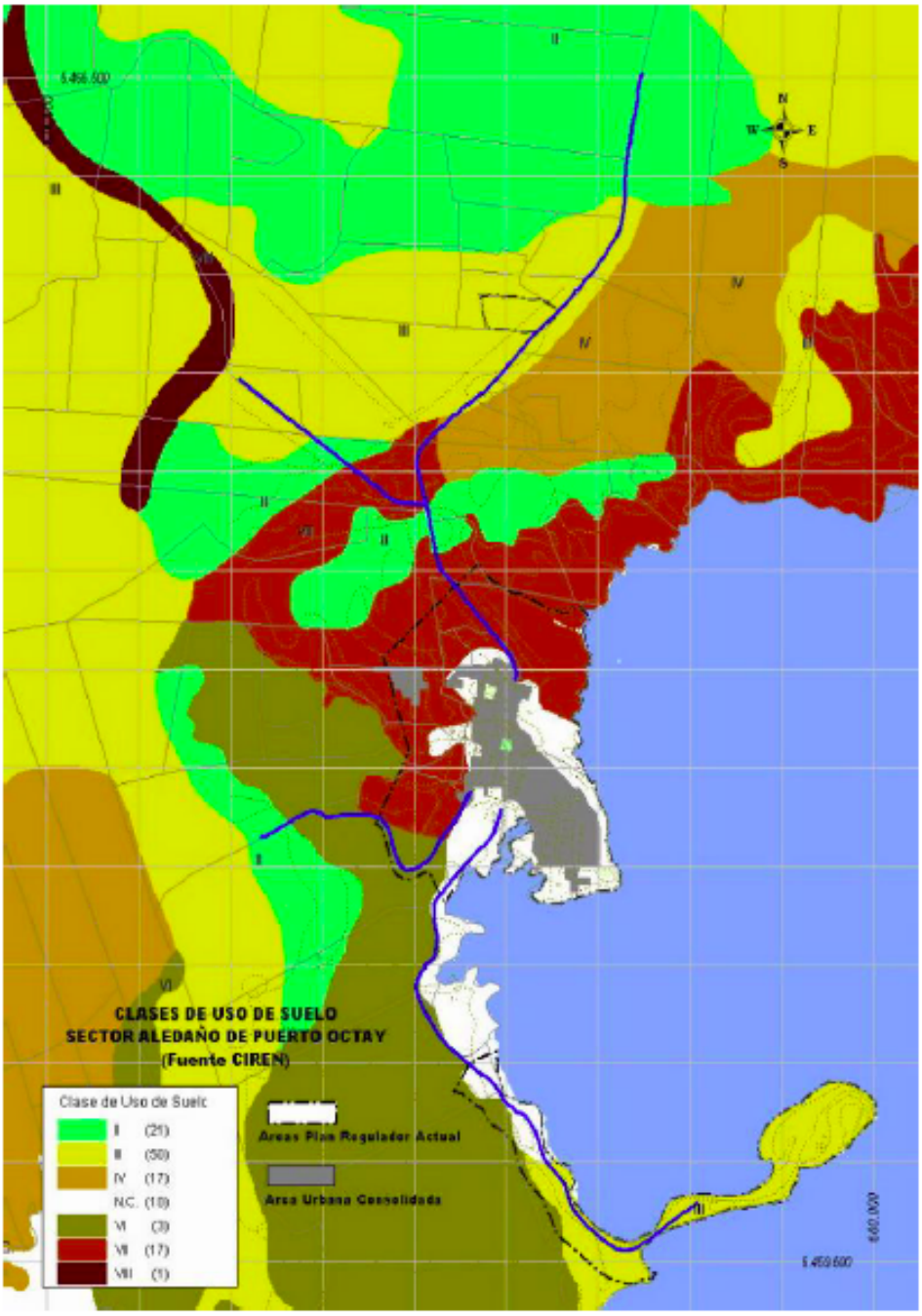
Figura 6: Curva IDF estación de Puerto Montt

Water quality levels Lake Llanquihue



Parámetros	Unidad	Puerto Octay	Frutillar	Ensenada	Puerto Varas
Conductividad	uS/cm	110	110	110	110
pH		6,5 – 8,5	6,5 – 8,5	6,5 – 8,5	6,5 – 8,5
Oxígeno disuelto	mg/l	> 8,5	> 8,5	> 8,5	> 8,5
Oxígeno disuelto	% Sat	> 85	> 85	> 85	> 85
Turbiedad	NTU	2,1	2,1	2,4	2,5
Sílice	mg/l	1,83	1,84	1,77	1,80
DQO	mg/l	4,8	4,9	6	5
Transparencia	m	> 13,5	> 14,0	> 16,0	> 12,5
Nitrógeno total	mg/l	0,12	0,14	0,13	0,13
Fósforo total	mg/l	0,01	0,01	0,01	0,01
Clorofila a	ug/l	1,4	1,4	1,4	1,4

Puerto Octay Soil Map



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