# Public Consultation on Lake Nicaragua

24 September 2015

HKND GROUP

K.W.PANG
Executive Vice President

# Introduction

- Lake Nicaragua is a critical element of the Project
- HKND is fully aware of the issues with the Lake & people's concern about the Canal's impact on the Lake
- HKND believes that all risks can be successfully managed
- Further detailed technical studies will be undertaken to ensure that the final Project design will protect the Lake

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# Major Fresh Water Source


International community's greatest concern on the Lake are:

- Water balance
- Salt intrusion
- Sediment increases
- Seismic hazards
- Security of the Locks
- Toxic material spill

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# Current Situation of the Lake

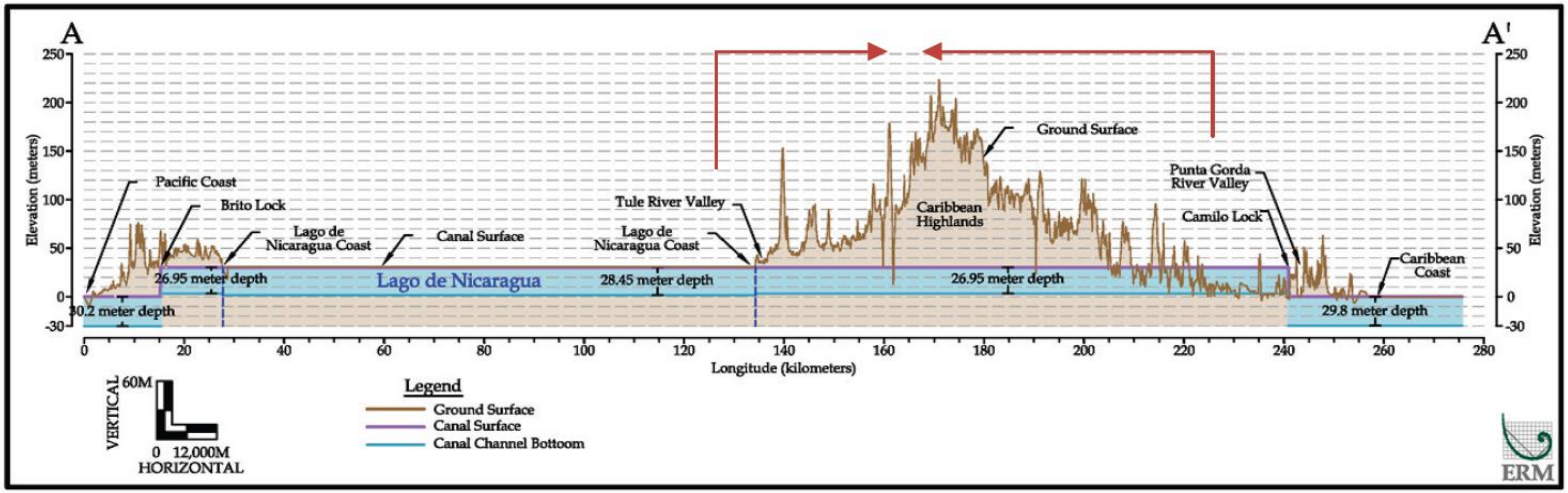
The lake is deteriorating even without the Canal:

- Increase in Sedimentation
- Water quality is getting worse
- Reduced water inflows causing lake level to drop
- More water consumption due to social usage
- Climate change will impact the lake further even without the canal

# Water Balance


- Impact of Canal on Water Balance is major concern
- With the Canal there will be NO NET USE OF LAKE NICARAGUA WATER
- Water usage is made up by diverting Rio Punta Gorda water into Lake
- With Canal, Lake water levels can be maintained to reflect current levels fluctuations

# Water System of Canal




- Canal will use water from the Punta Gorda watershed that currently flows into the Caribbean
- Agua Zarca Reservoir will store additional water for El Nino events & climate change
- Water diverted from east to west will maintain Lake water levels.

Table 2-2 Lake Nicaragua hydrologic characteristics (source: ERM, 2014)

| Aspect | Units | Value |
|---|---|---|
| Average annual evaporation rate | mm/year | 2,389 |
| Average annual precipitation | mm/year | 2,229 |
| Calculated total annual outflow | $10^6$ m³/year | 12,858 |
| Annual average outflow to Rio San Juan as measured at Loma del Gallo gauge | $10^6$ m³/year | 10,358 |

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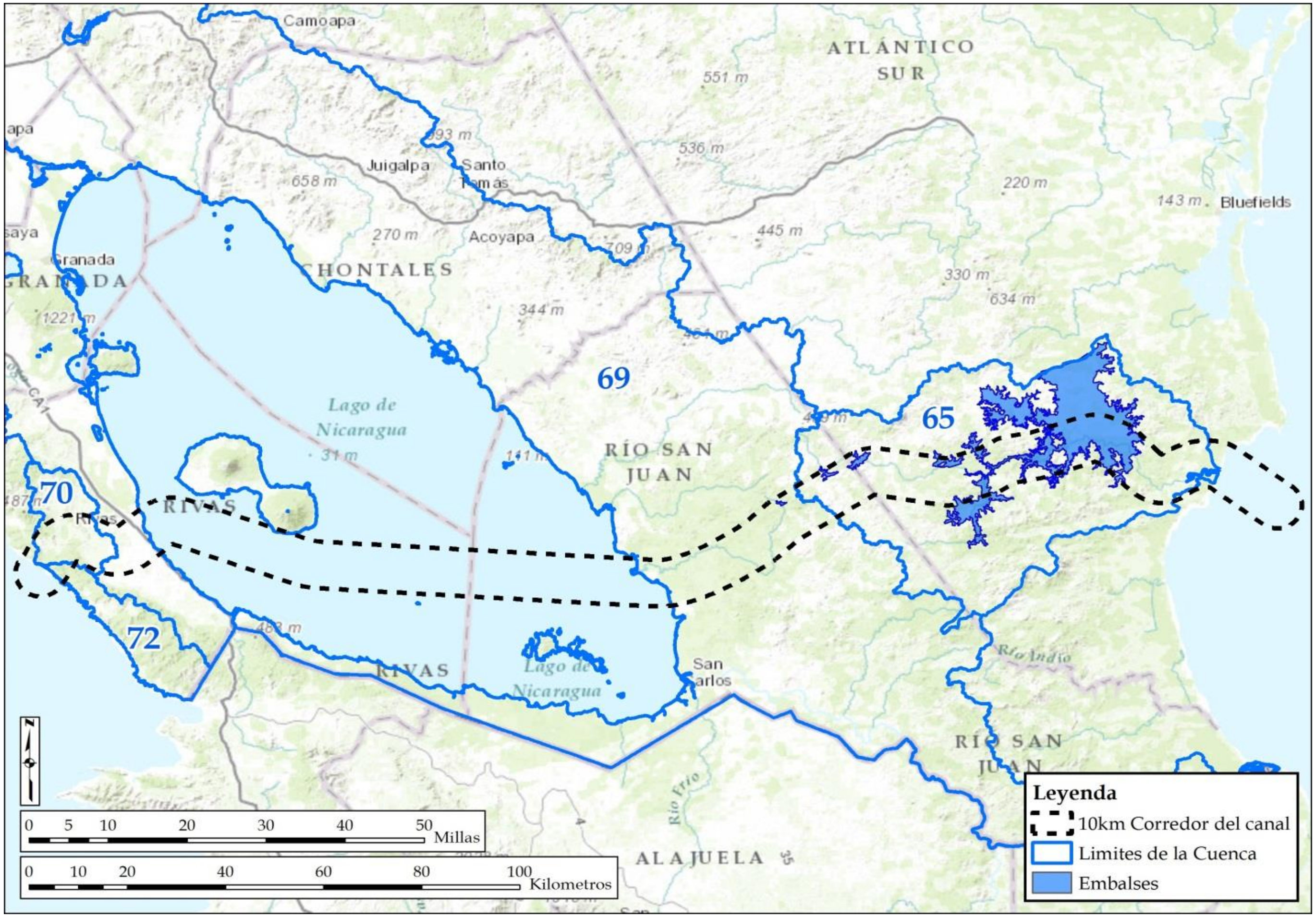
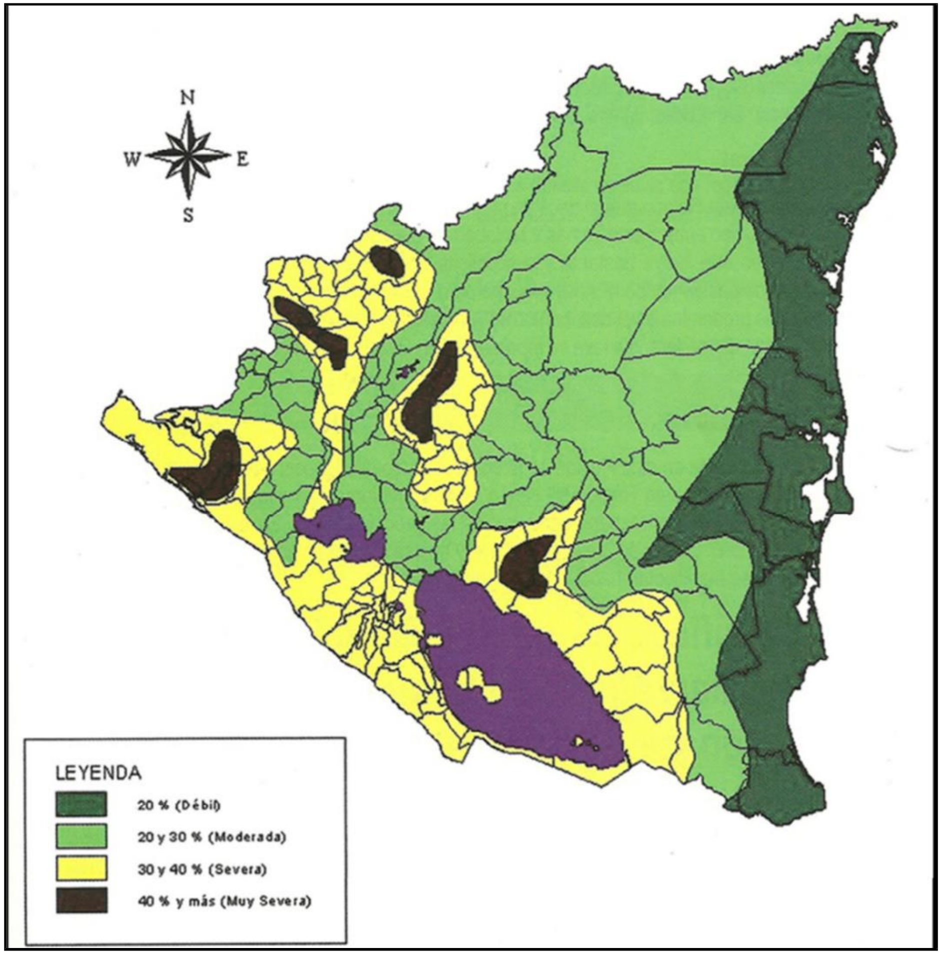
# Rio San Juan Watershed




- Rio San Juan watershed is roughly the same as the Lake's watershed
- With the Canal the Rio Punta Gorda's watershed will be added
- More water available for control of Lake level.

# Severity of drought induced by El Nino




- 1972 drought
  - Strongest in history; deficit of rainfall 35%
  - Very severe in the Pacific North and Central Regions
- Climate change
  - Due to climate change, overall rainfall could be reduced by 15%
- Agua Zarca Reservoir will provide "make-up" water

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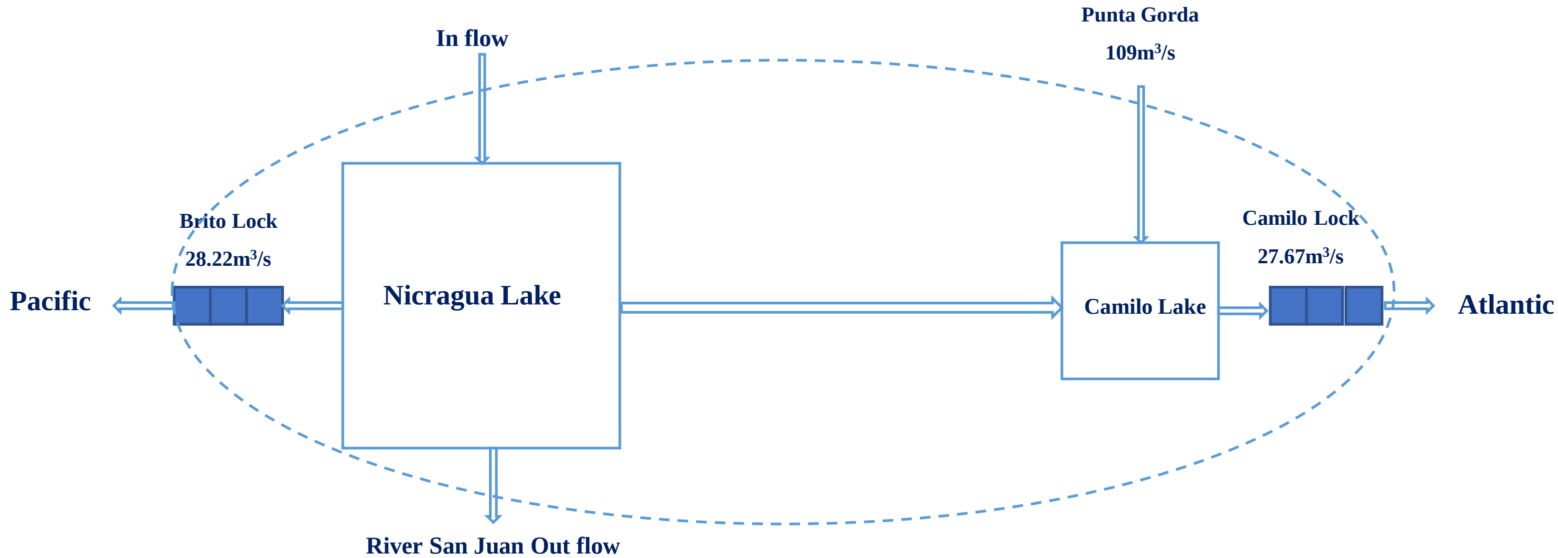
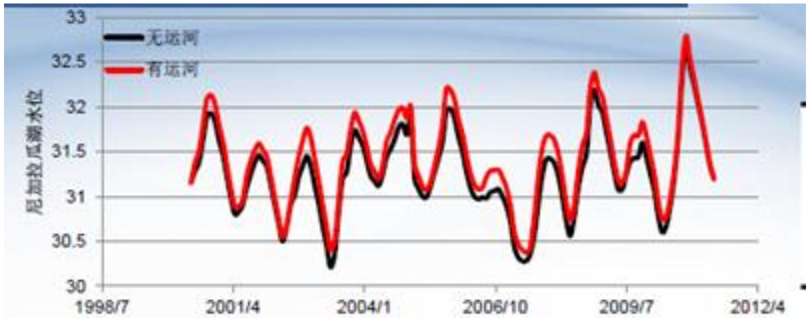
# Water Supply Modelling

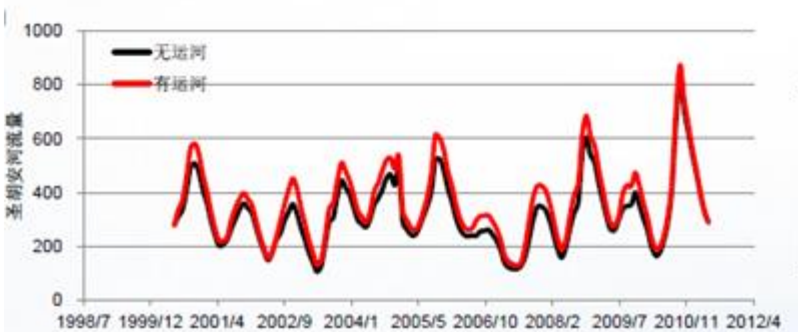



**Annual average runoff above Camilo ship lock of Punta Gorda River is 111 $m^3/s$（2000.1~2012.12）. Removing the social and economic water use of the basin， there remains about 109 $m^3/s$ runoff volumes to satisfy the operation of the canal ship locks. In dry season from January to April， the average flow rate is only 25.8 $m^3/s$， so the available storage of Lake Nicaragua and Camilo reservoir need to be used to satisfy the water demand of the ship locks.**

$$W_{T2} = W_{T1} + W_{NLin} + W_{PGin} - W_{NLout} - W_{NC} - W_{Env} - W_{Eco} - W_{ET}$$

# Lake & Rio San Juan water levels




With Canal, water levels & fluctuations will mirror current conditions

## (3) 尼加拉瓜湖影响分析/Influence Analysis of Lake Nicaragua

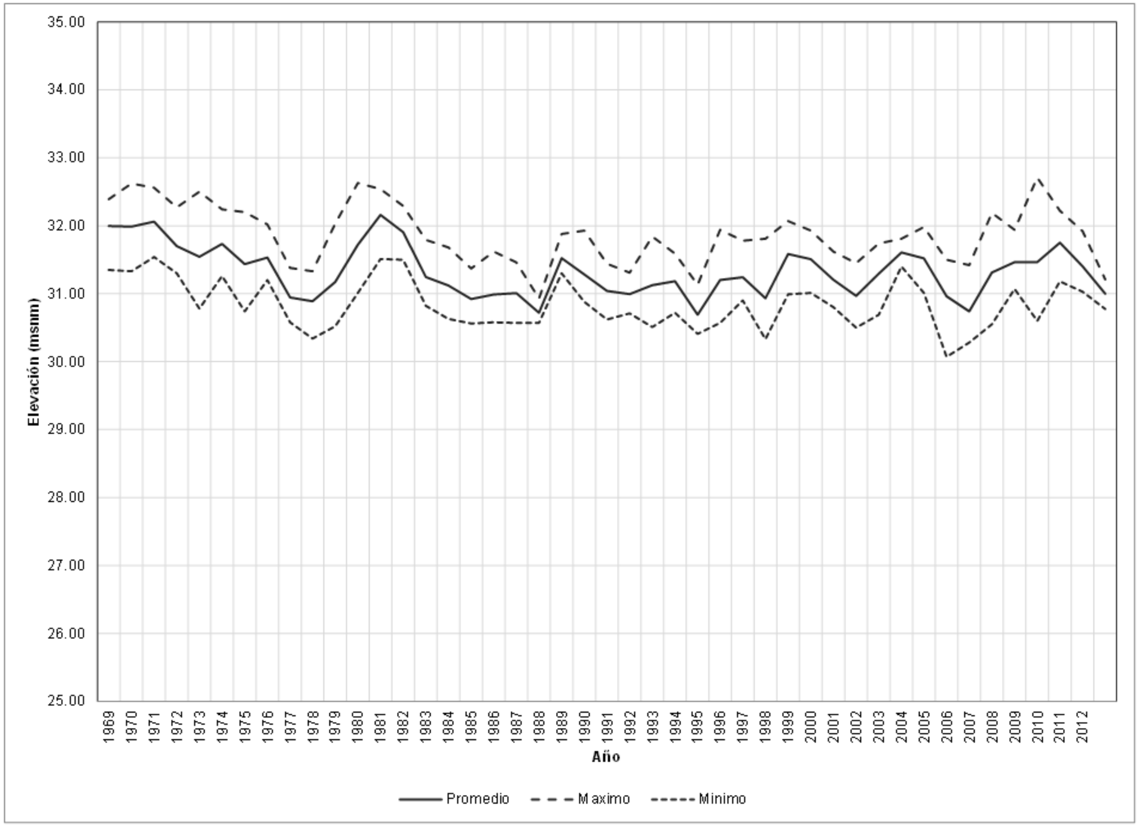
尼加拉瓜湖水位（m）
Water level of Lake Nicaragua (m)

| | 无运河 original | 有运河 With canal | 有无对比 comparison |
|---|---|---|---|
| 最大 max | 32.69 | 32.8 | +0.11 |
| 最小 min | 30.21 | 30.38 | +0.17 |
| 平均 avg | 31.26 | 31.42 | +0.16 |

圣胡安河流量（m³/s）
Runoff of San Juan River(m³/s)

| | 无运河 original | 有运河 With canal | 有无对比 comparison |
|---|---|---|---|
| 最大 max | 822 | 874 | +52 |
| 最小 min | 105 | 128 | +23 |
| 平均 avg | 319 | 363 | +44 |

# Historical Lake water levels




Source: Data from INETER

**Figure 5.7-46: Lago de Nicaragua Water Surface Elevation (1969-2013)**

- Historical maximums not to be exceeded in high rainfall events so that Rio San Juan water levels are not increased
- Water levels adjusted by releasing water for salt flushing and river environmental flows

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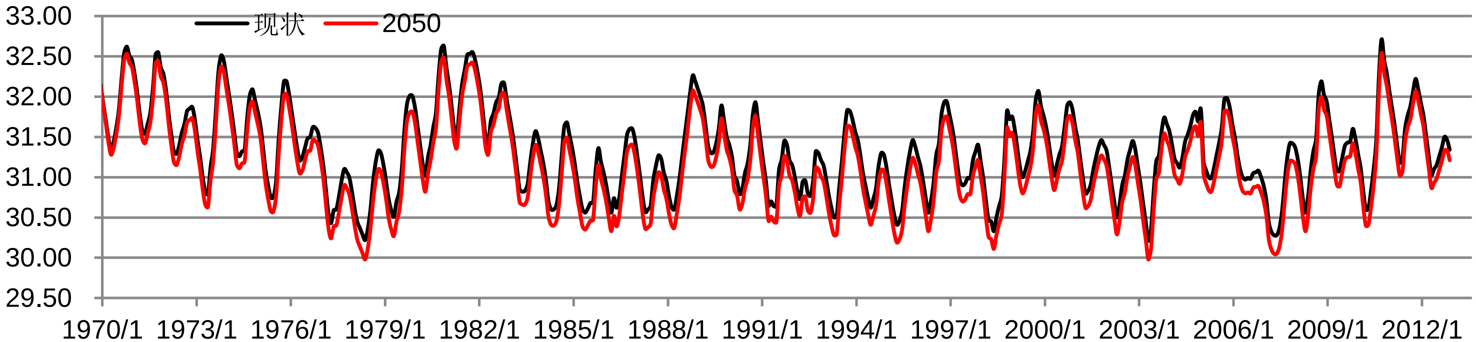
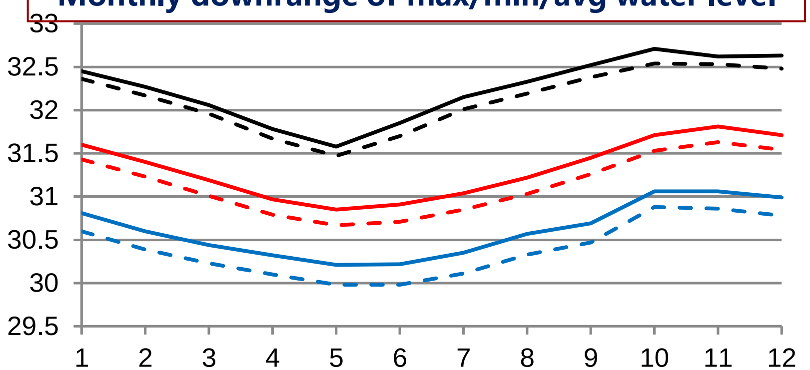
# Social Water Demand impact on water levels – without Canal

| | 单位/units | 2012年 | 2050年 | 增加需水量/water requirement increment |
|---|---|---|---|---|
| 人口population | 万人（10 thousands） | 309 | 394 | |
| 用水指标 | m³/人.年（per person per） year | 300 | 600 | |
| 需水量water requirement | 亿（0.1 billion m³） | 9.27 | 23.64 | 14.37 |

**Taken increment of social and economic water consumption into consideration, monthly series regulation(1970.1~2012.12) of Lake Nicaragua is calculated as follows.**




**Monthly downrange of max/min/avg water level**

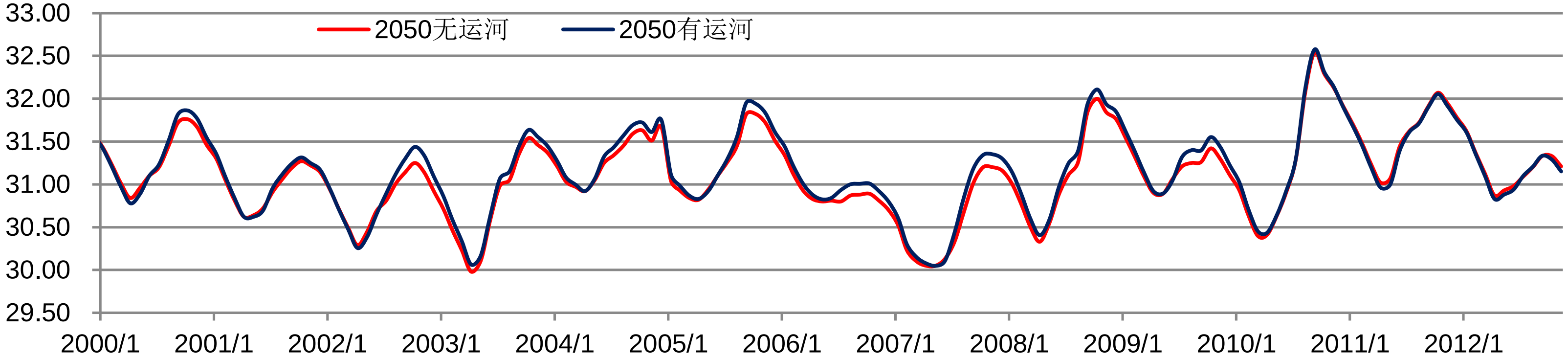



**Downrange of max/min/avg water level**

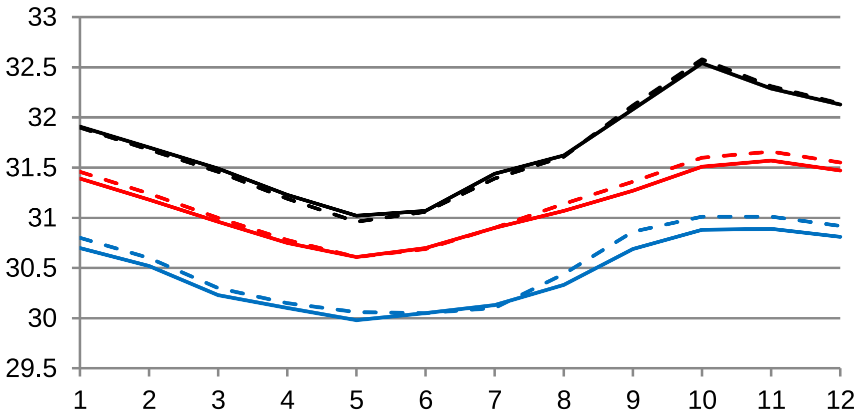
| | 最大max | 最小min | 平均avg |
|---|---|---|---|
| 现状present | 32.71 | 30.21 | 31.32 |
| 2050年 | 32.54 | 29.98 | 31.11 |
| 变化change | -0.17 | -0.23 | -0.18 |

# Social Water Demand impact on water levels – with Canal

**Based on the result of water balance calculation of Lake Nicaragua(from 2000.1~2012.12, taken increment of social and economic water consumption into consideration), the influence that canal would have on Lake Nicaragua’s water level is analyzed as follows.**




**Comparison among max/min/avg water level in each month**




**Comparison among max/min/avg water level**

| | 最大max | 最小min | 平均avg |
|---|---|---|---|
| 无运河 With canal | 32.54 | 29.98 | 31.11 |
| 有运河 Without canal | 32.58 | 30.05 | 31.17 |
| 增加 increment | +0.04 | +0.07 | +0.05 |

# Water Saving Basin Design

- 3 water saving basins per lock chamber required
- 60 % less water consumption then without WSBs

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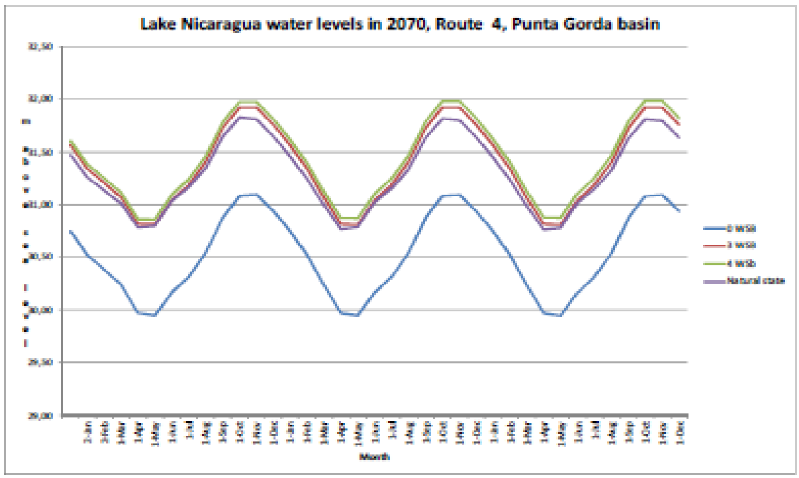
# El Nino Events

## Extreme event (El Niño) with canal
### with full gravity-driven natural inflow from Atlantic basins

- Balance model, Route 4

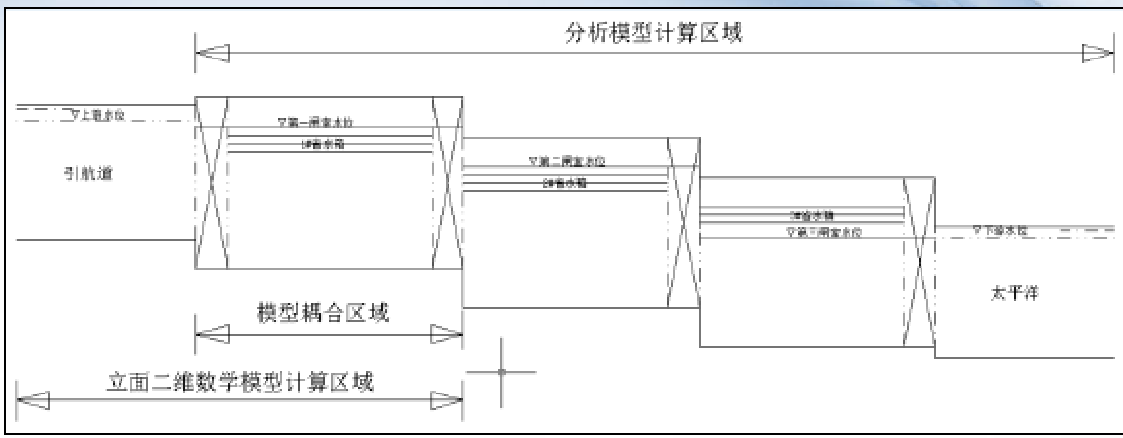
| | Equilibrium levels | 2070 | | |
|---|---|---|---|---|
| Lock configuration | 0 WSB | 3 WSB | 4 WSB | Natural State |
| Water use [m³/s] | 190.3 | 76.1 | 63.4 | 0 |
| Eq. level [masl] | 30.54 | 31.38 | 31.44 | 31.31 |
| Min. level [masl] | 29.95 | 30.81 | 30.88 | 30.76 |
| Ave. delta level [m] | -0.77 | 0.07 | 0.13 | 0.00 |
| Max. delta level [m] | -1.36 | -0.50 | -0.43 | - 0.54 |
| Ave. surface area [km²] | 6717 | 8447 | 8581 | 8274 |
| Q average San Juan [m³/s] | 160 | 339 | 357 | 319 |



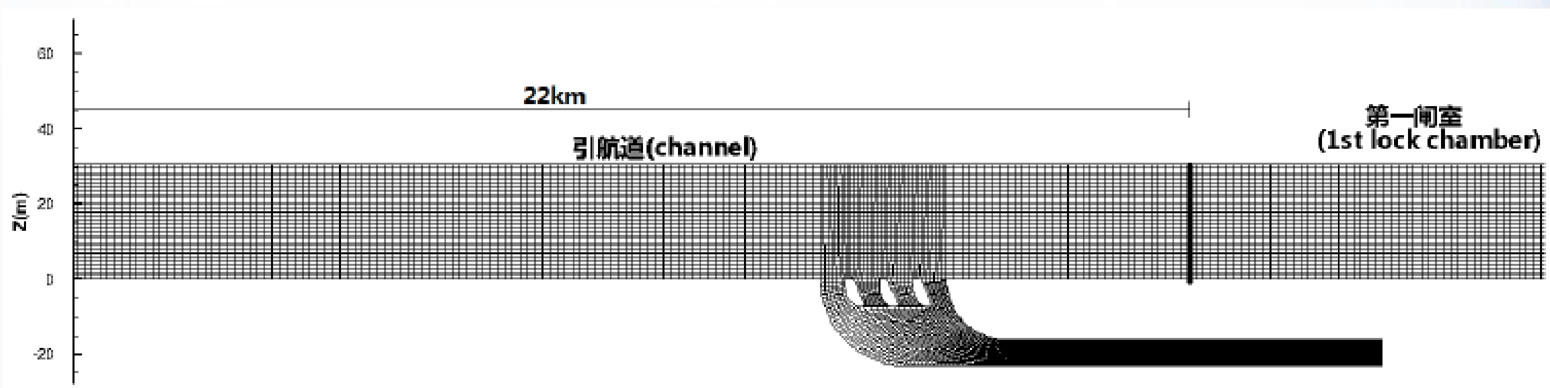

- 3 Water Saving Basins
- SBE study shows no significant water level impact from one El Nino event

SBE Deltares

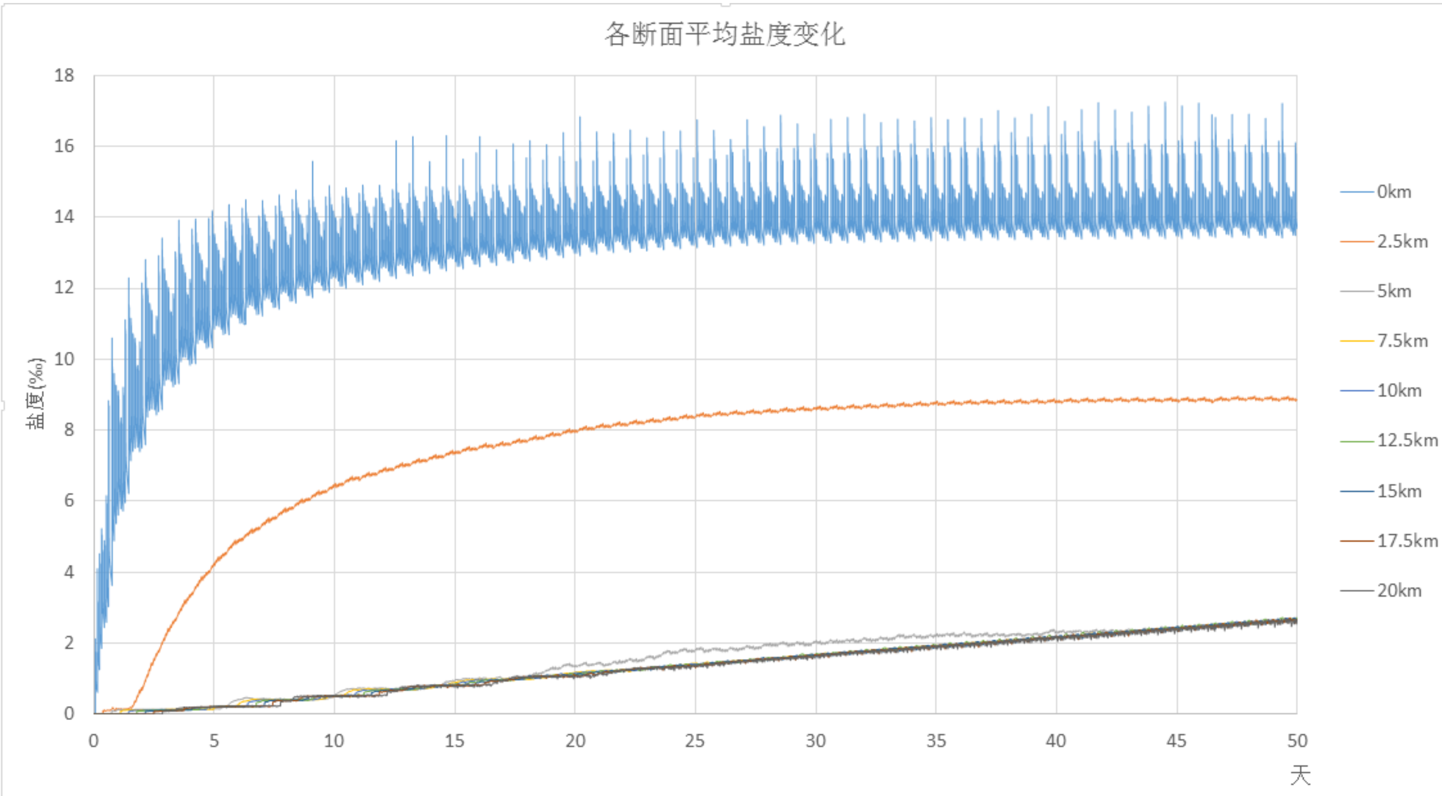
# Salt Intrusion Modelling – Calculation Model




垂面二维模型/ vertical 2D mathematical model



# Salt Intrusion Modelling – without mitigation




- ChangJiang Simulations shows significant salinity increases for first 10 days
- Salinity stabilizes from 40 days
- At 5 km upstream salinity increase is minimal
- At 5 km upstream salinity stabilizes at 2.0‰ after 37 days

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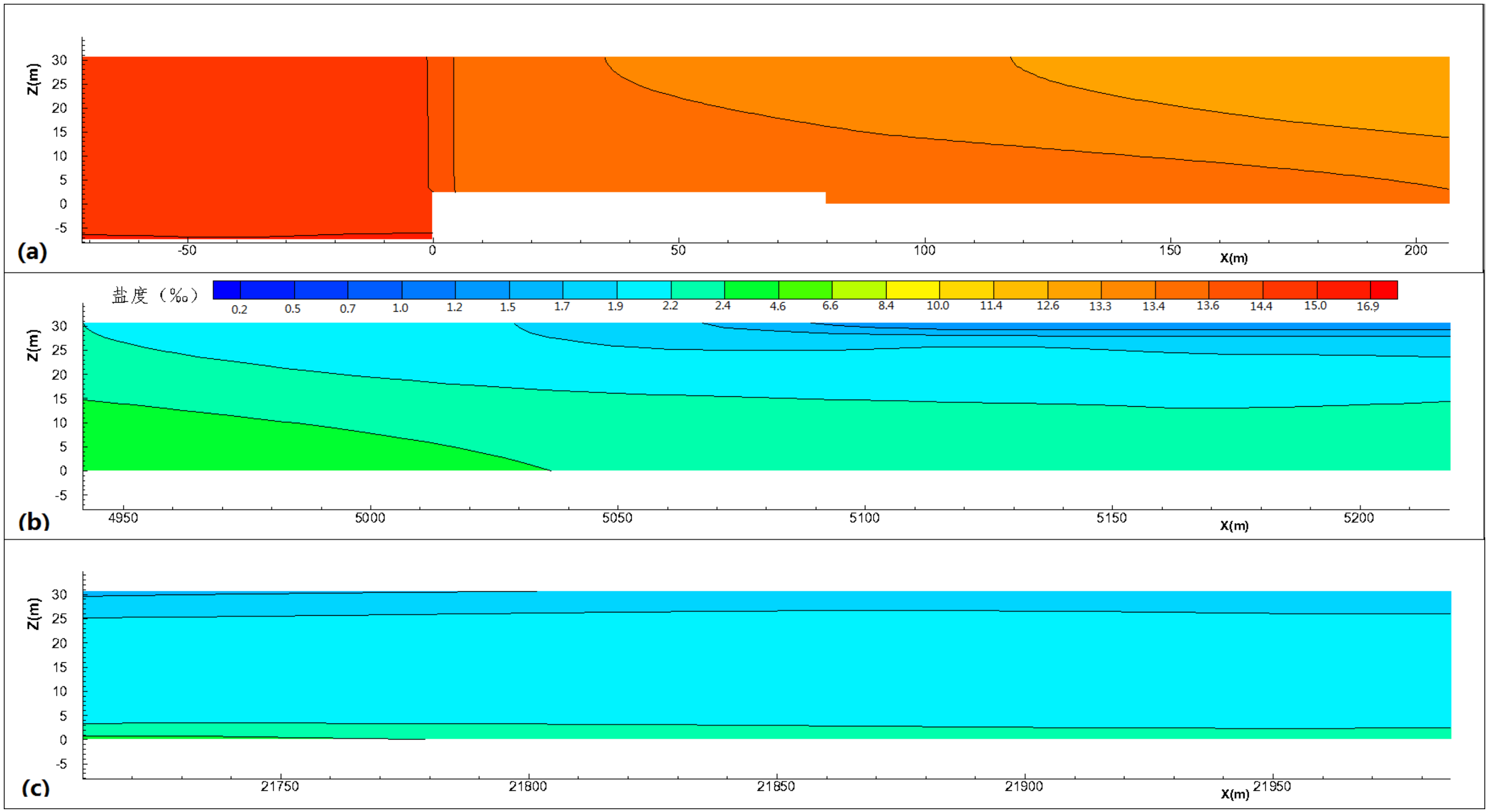
# Salt Intrusion Modelling - distribution




5 km upstream salt settles to bottom

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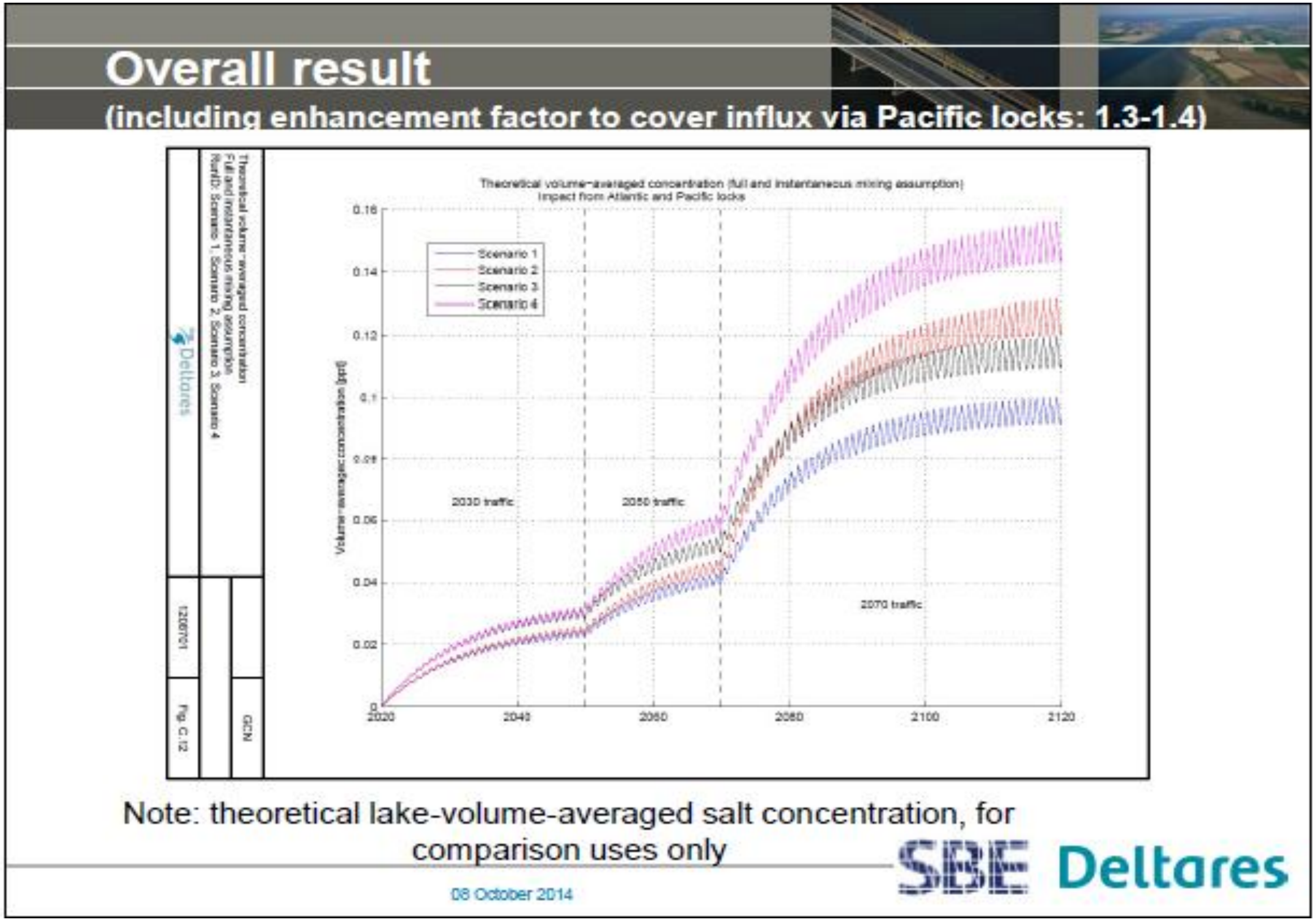
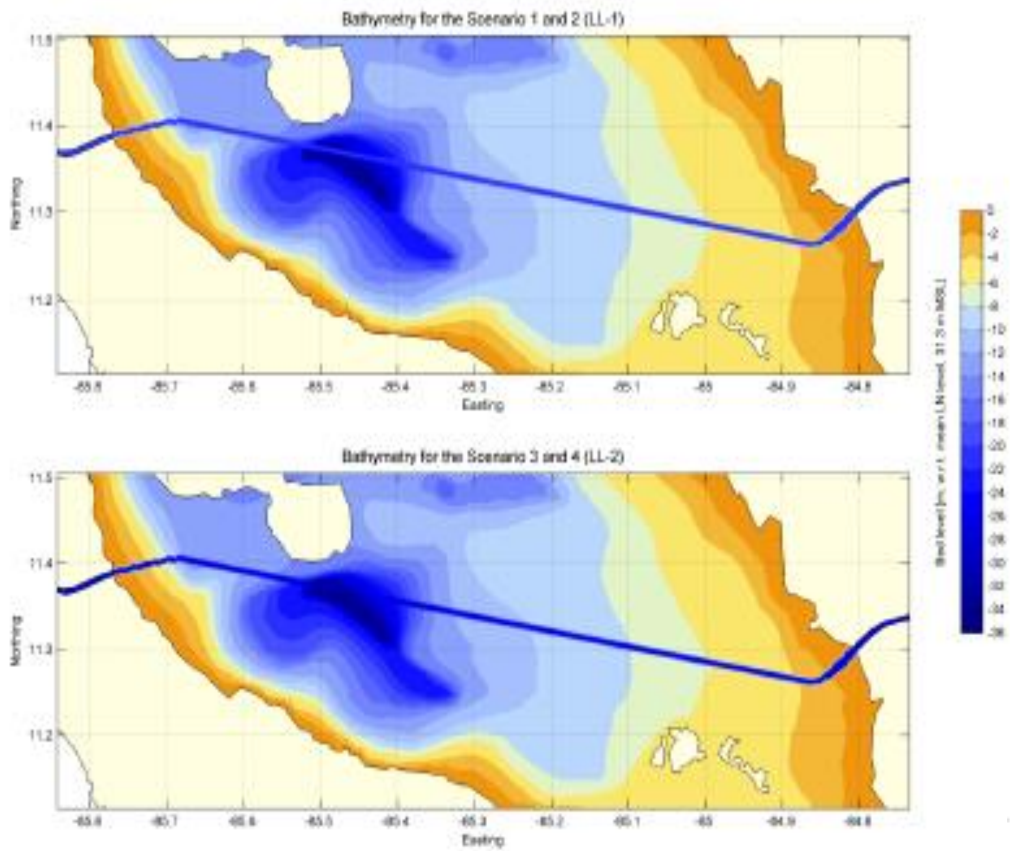
# Salt Intrusion Modelling – without mitigation




Impact of increased traffic volume (2030, 2050, 2070)

# Salt Intrusion Modelling




SBE Deltares

- Higher concentrations around inflow areas
- Deeper sections will collect more of the heavier salt water
- Salt "hotspots" (in both Canal and Lake)

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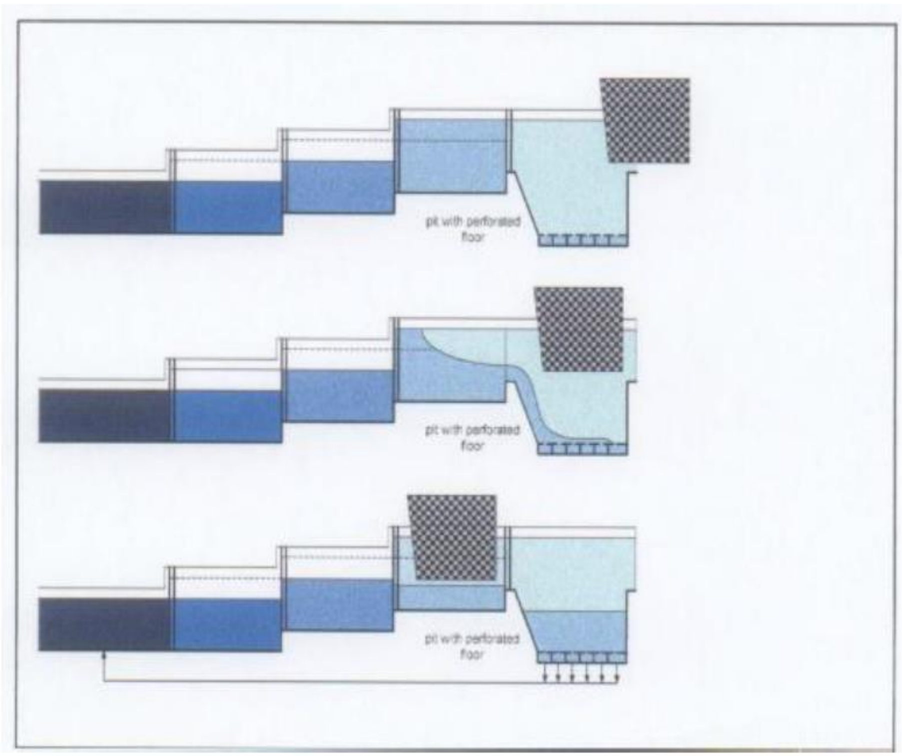
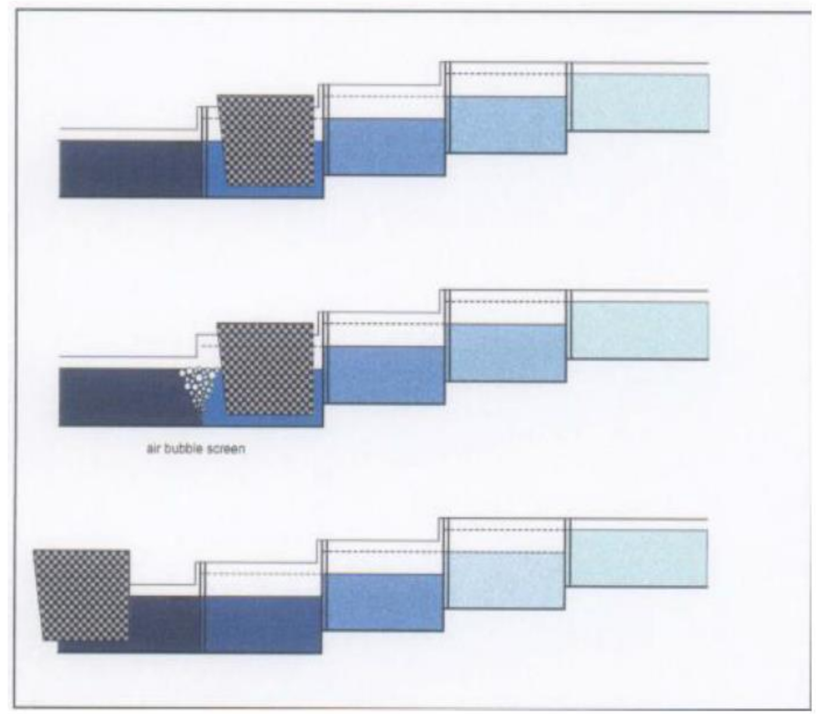
# Salinity Mitigation Measures - Alternatives



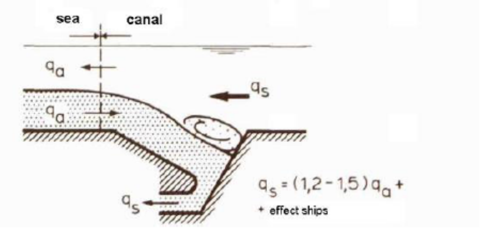

Flushing of salt water from pit with perforated floor

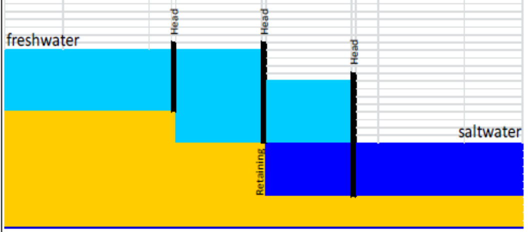



Pneumatic barrier at the entrance to lower and upper lock chamber

# Salinity Mitigation Measures - Alternatives

| measure | Effectiveness of prevention of salt intrusion | range | remarks |
|---|---|---|---|
| Flushing collected water, selective withdrawal | Good effectiveness | Salt intrusion max 20 – 30% of upper lock chamber content above the level of the upward step in the bottom (1008 kg/m$^3$, brackish water)<br>Freshwater loss = 180 - 220% of lock chamber content. idem<br><br>If combined with pneumatic barrier: salt intrusion max 15– 20%; about same freshwater loss. | Probably no time loss.<br><br>Result very much depends on a well-designed and well-operated flushing system. |
| Retaining wall concept | High effectiveness | Salt intrusion 5 – 15% of (double head) lock chamber content (1024 kg/m$^3$, salt water)<br><br>Freshwater loss = 10 – 20% of (double head) lock chamber content. | Probably no additional time loss for a single passing vessel, but the frequency of lockages of lower lock will be lower.<br><br>Forces on vessels need attention (pneumatic barriers are advised)<br><br>Still requires significant efforts in development and for verification of feasibility. |

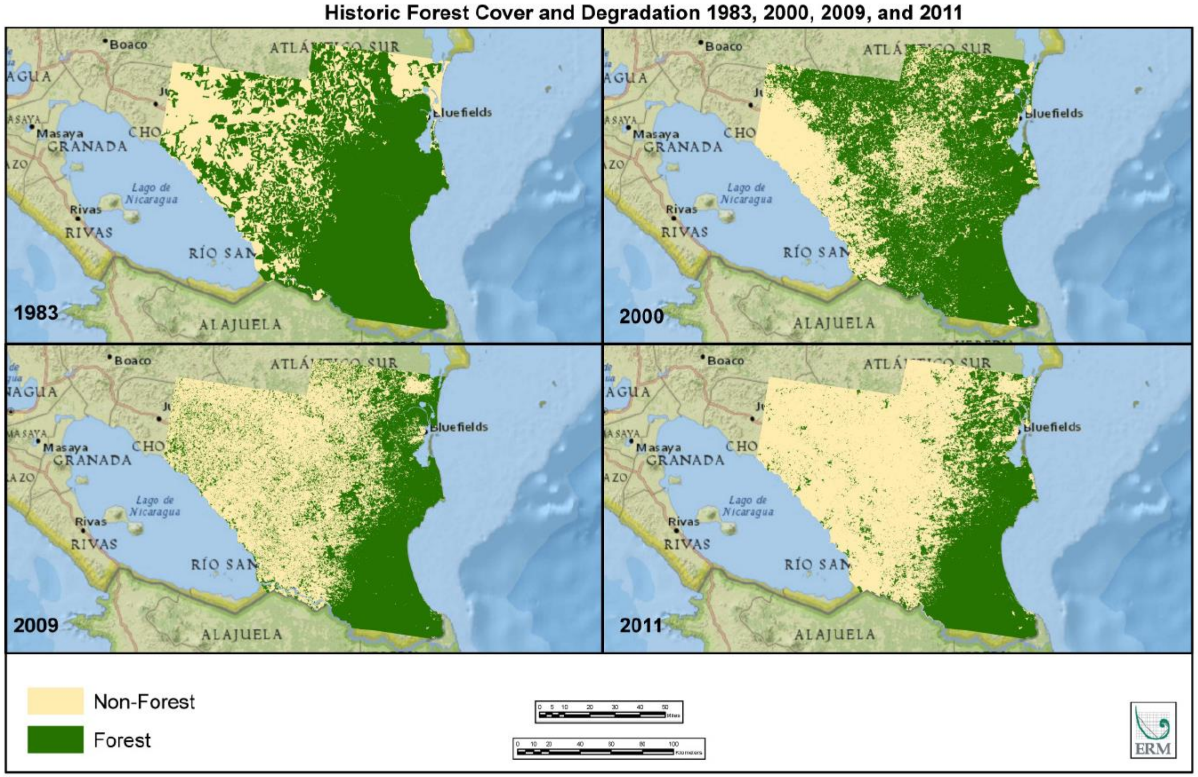





SBE Deltares

# Sedimentation – Forest lost issues




- Without Canal, sedimentation will increase because of land clearing
- Over the past 30 years, the Lake Nicaragua watershed has lost much of its forest cover due to cattle farming and agriculture.
- This and the slope gradients of the watershed increase the runoff and soil erosion.
- World Bank (2013a) estimates 13.3 tons of sediment generated per hectar
- Increased erosion and runoff cause increased nutrient loading in Lake

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# Sedimentation – River sediment loads

- Currently rivers flowing into Lake all carry large sediment loads
- Without Canal, sedimentation of Lake will continue

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# Sedimentation – issues

- Lake currently has serious sediment issue
- Sediment destroys animal life and vegetation
- Sediment reduces sunlight penetration

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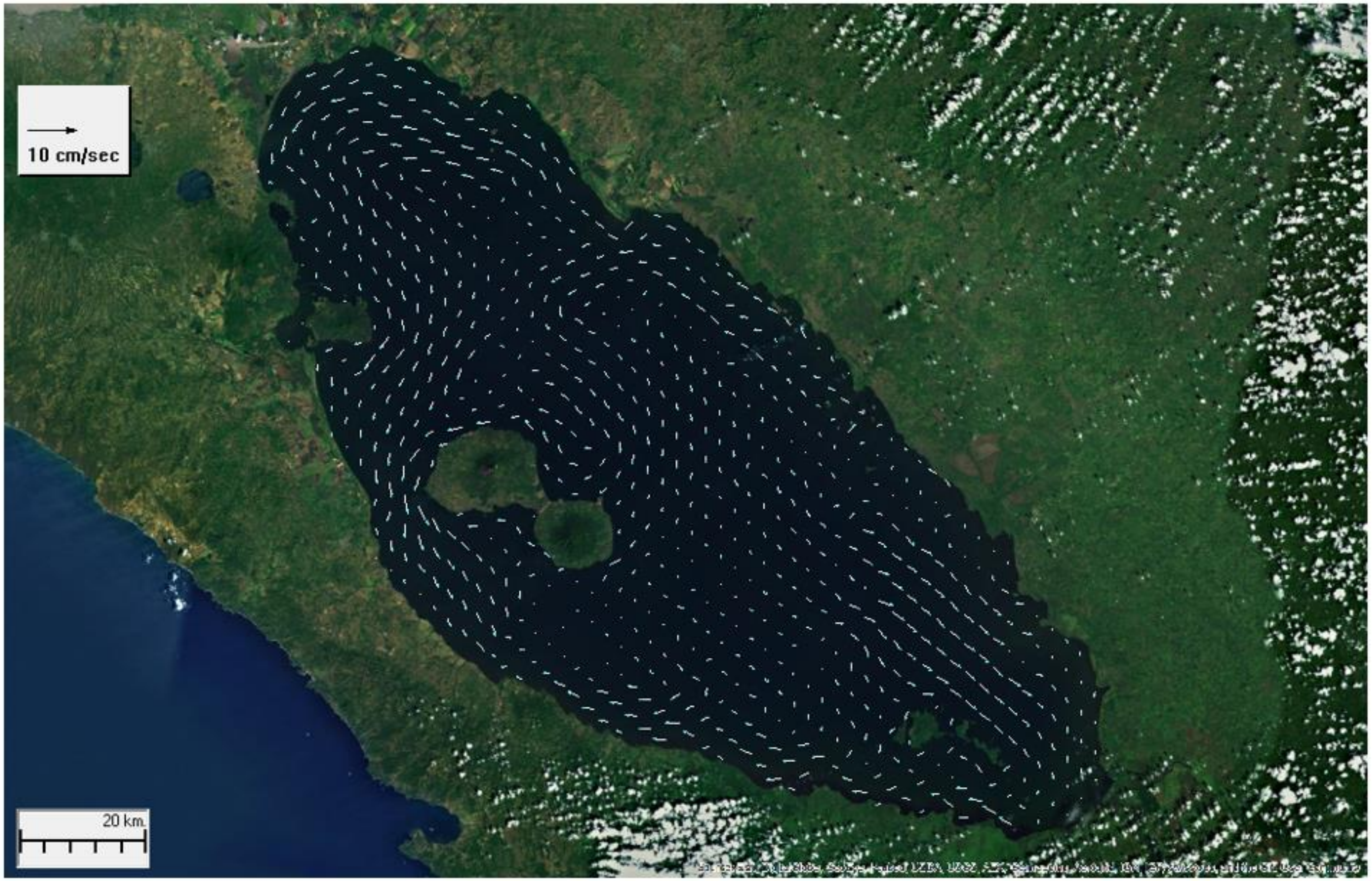
# Sedimentation – Lake Nicaragua water circulation




Natural north–south circulation pattern pushes sediment towards the southern part of the Lake

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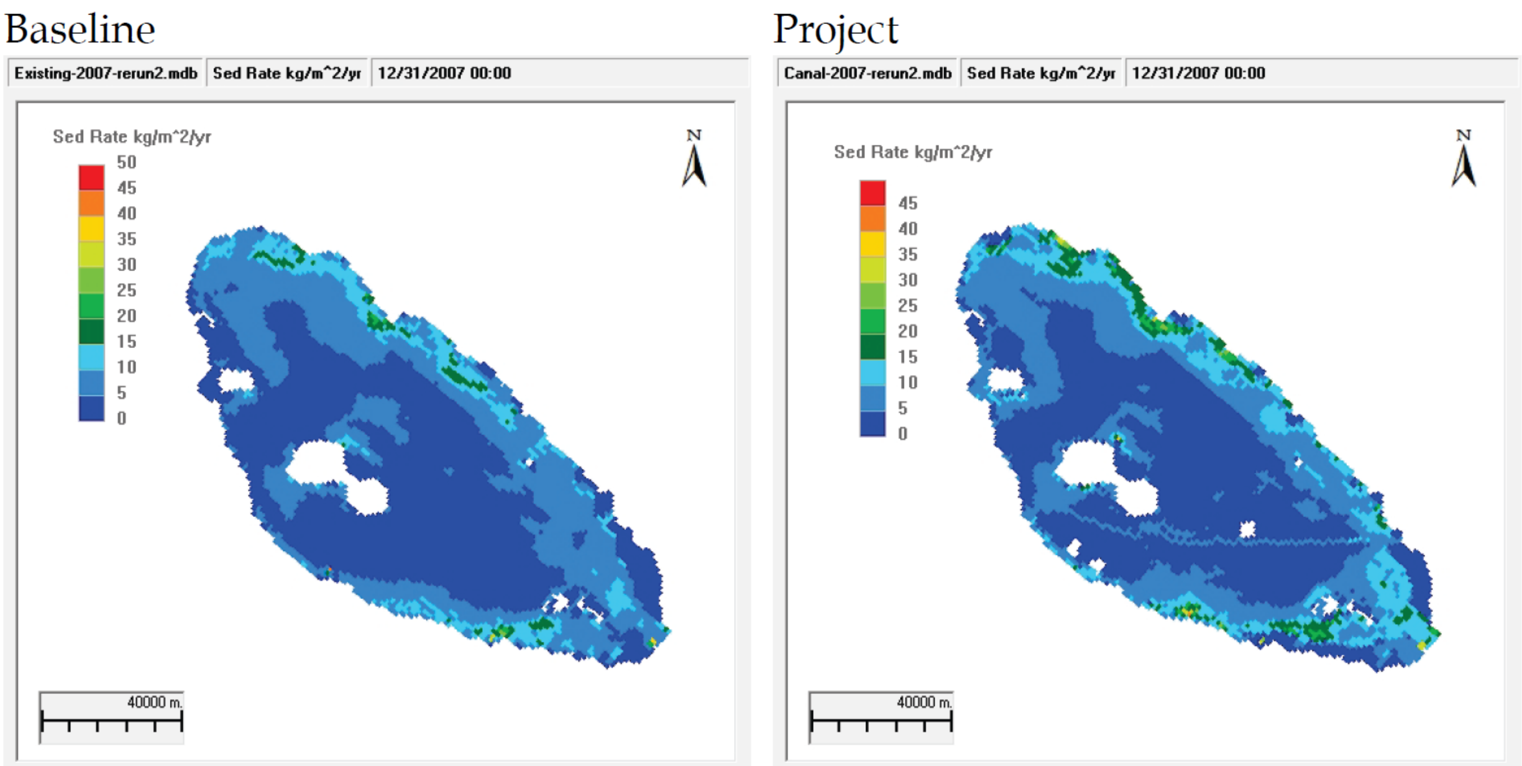
# Sedimentation – with Canal

**Figure 4-12 Net sedimentation rate on Dec 31, existing and with project**




- Canal will not increase sedimentation of Lake
- With Canal, sedimentation will reduce because of reforestation program

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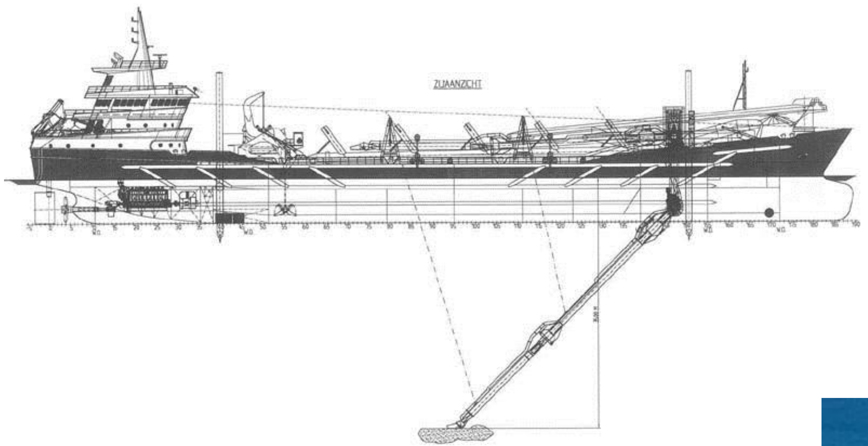
# Excavation in Lake – equipment




- Modern trailer hopper suction dredge
- Sucks material hydraulically into ship for transport

- Ship offloads material to form island

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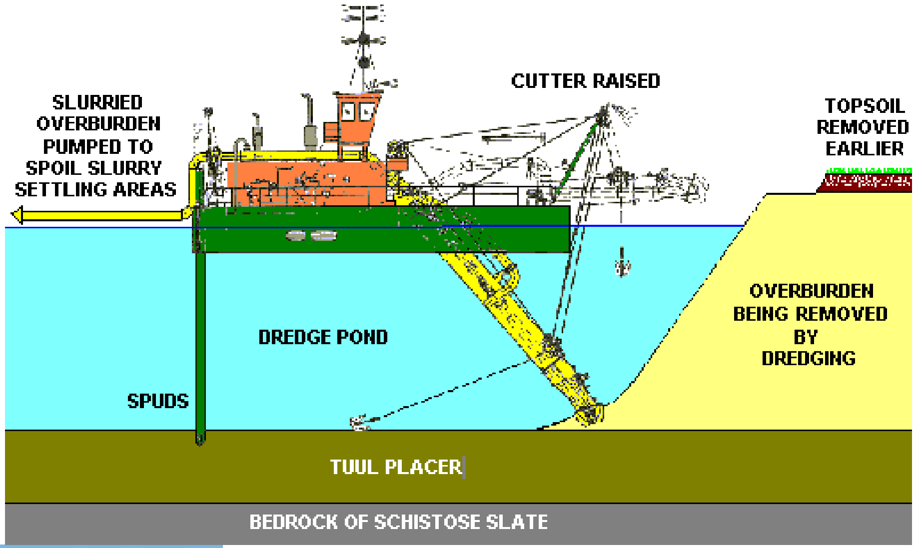
# Excavation in Lake - No blasting

Modern Cutter Suction Dredgers can excavate soft rock to hardness of 40.

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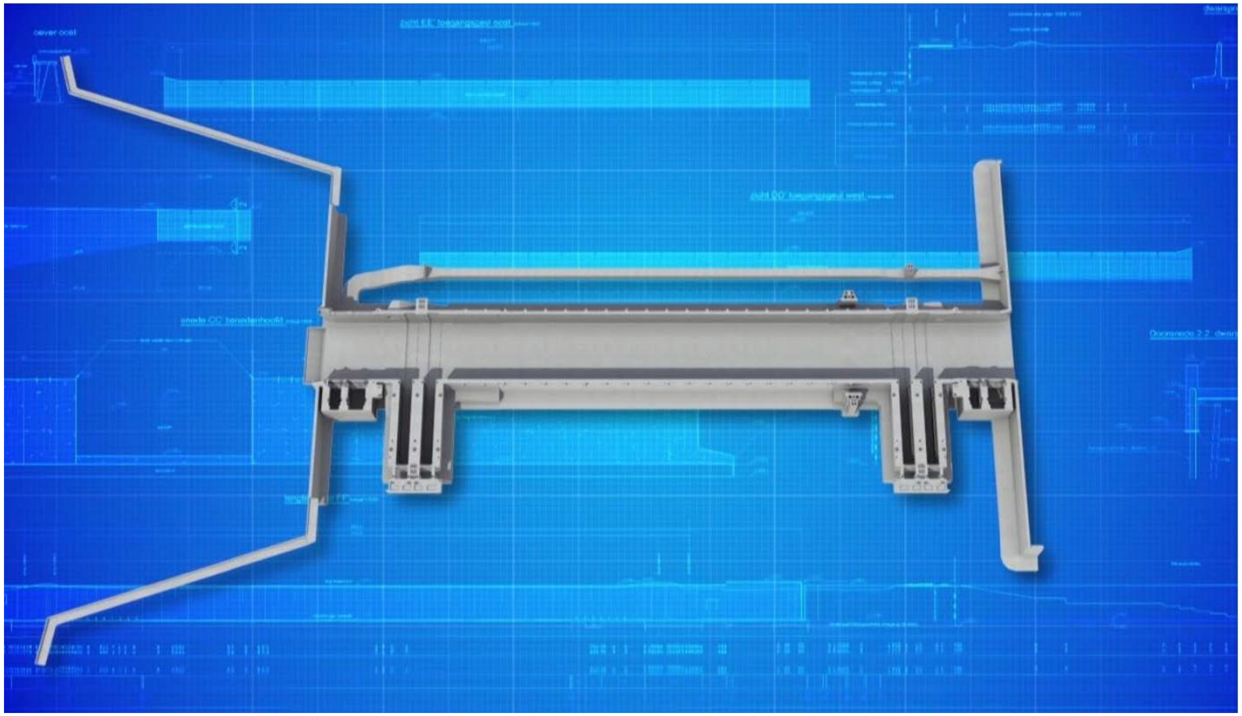
# Lock Risks – Design



- Locks designed for 1 in 10,000 year catastrophic risk event
- Seismic design to World's Best Practice
- Proven technology

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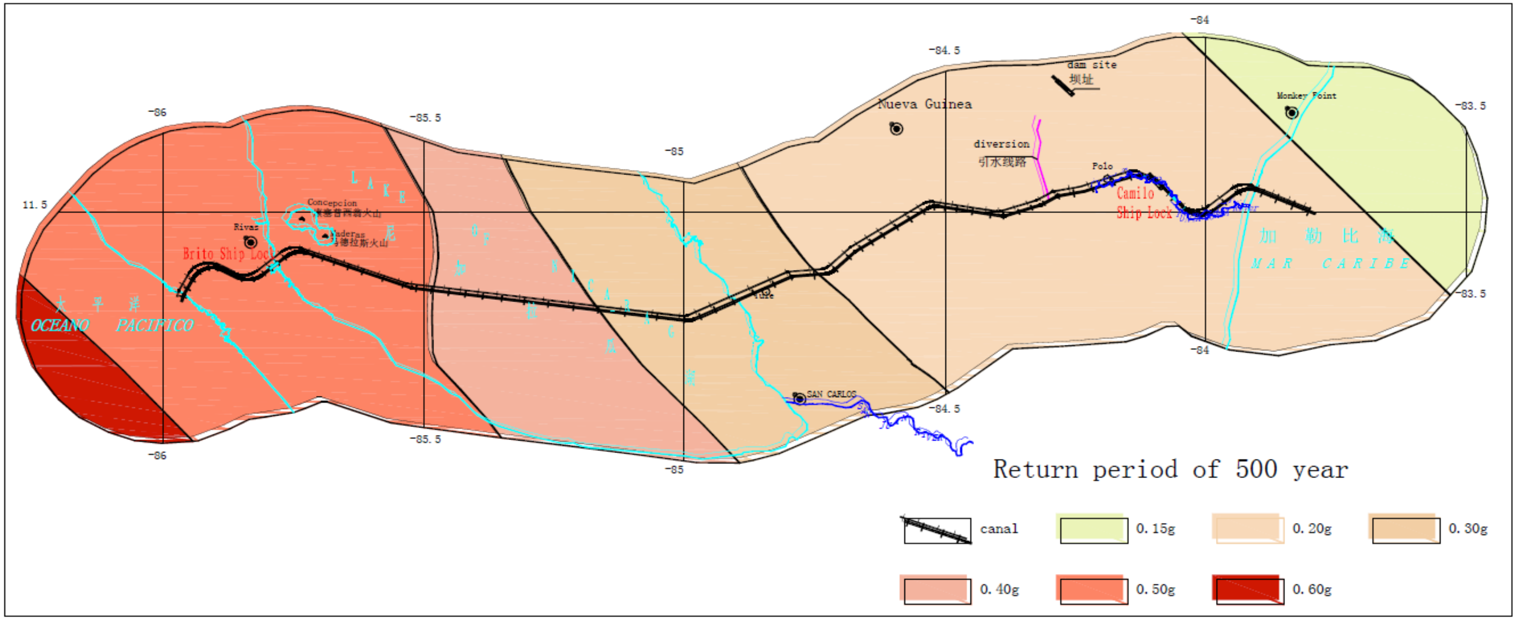
# Lock Risks – Earthquake




Zoning map of horizontal ground peak acceleration at the exceeding probability of 10% in 50 years along the Canal.

- Seismic events are the major risk
- West Canal is in worst seismic zone

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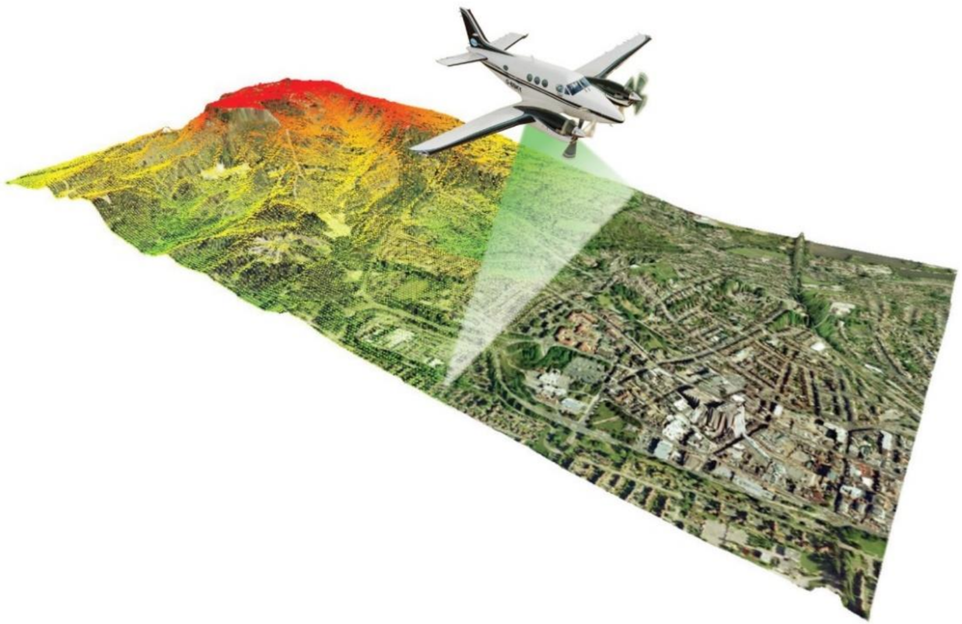
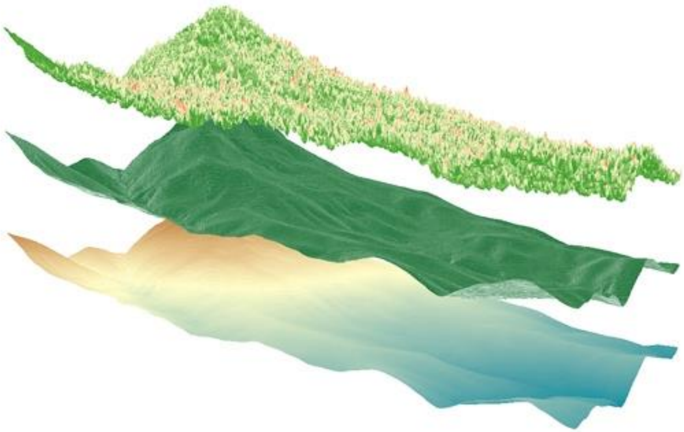
# Topographic Survey – LiDAR





- LiDAR radar scanning "sees" through vegetation
- Very accurate surface levels
- Can map vegetation type
- Can do Lake bathymetry in shallow water
- Can indicate subsurface water

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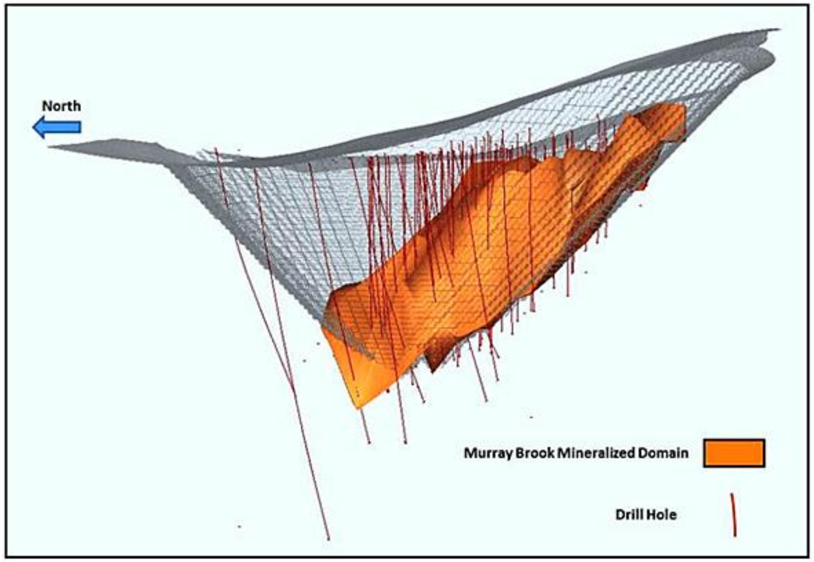
# Survey – Geophysical Magnetic

- Magnetic survey will detect different ground material conditions




- Can describe material to be excavated
- Will locate hard material
- Can identify areas of high liquefaction risk

# Field Investigation – Borehole drilling


- Borehole data is most accurate
- Drilling program to be undertaken for full length of the project

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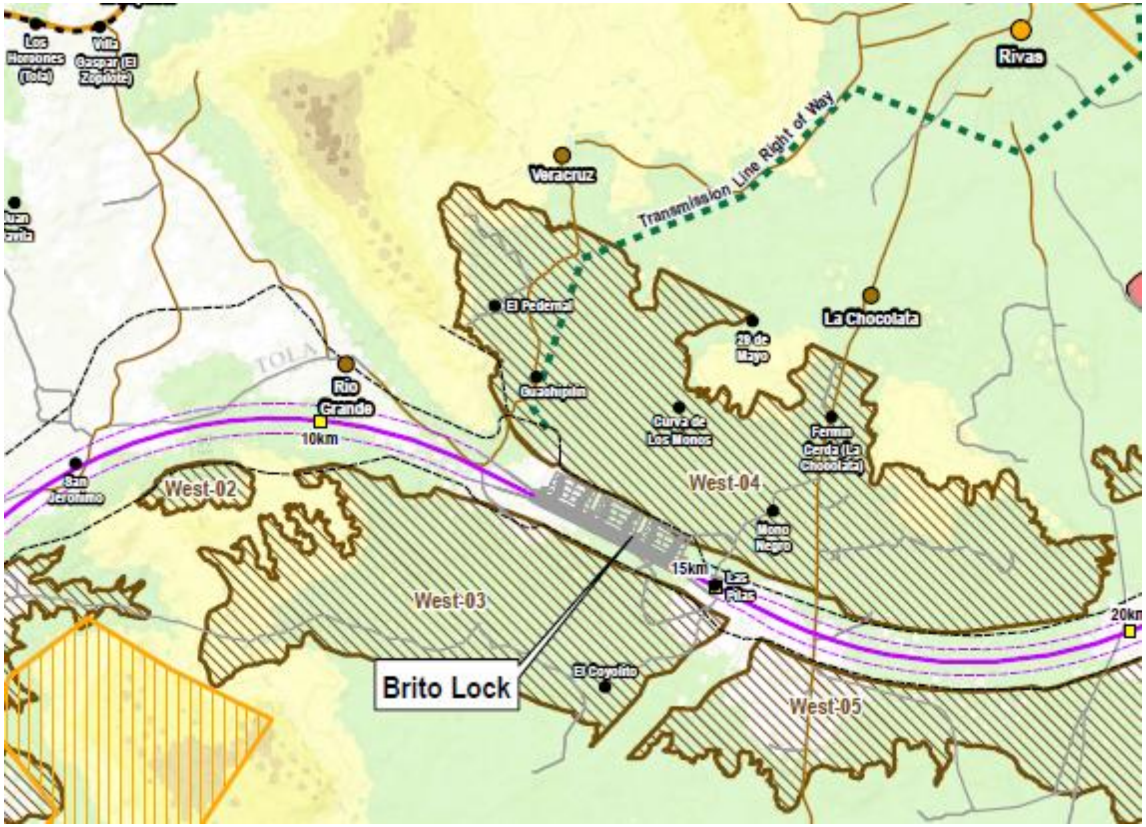
# Locks – Brito Lock




- Lock is located 13 km inland to minimize Seismic & Tsunami risks
- Best foundation conditions
- Reduced land inundation by poundage

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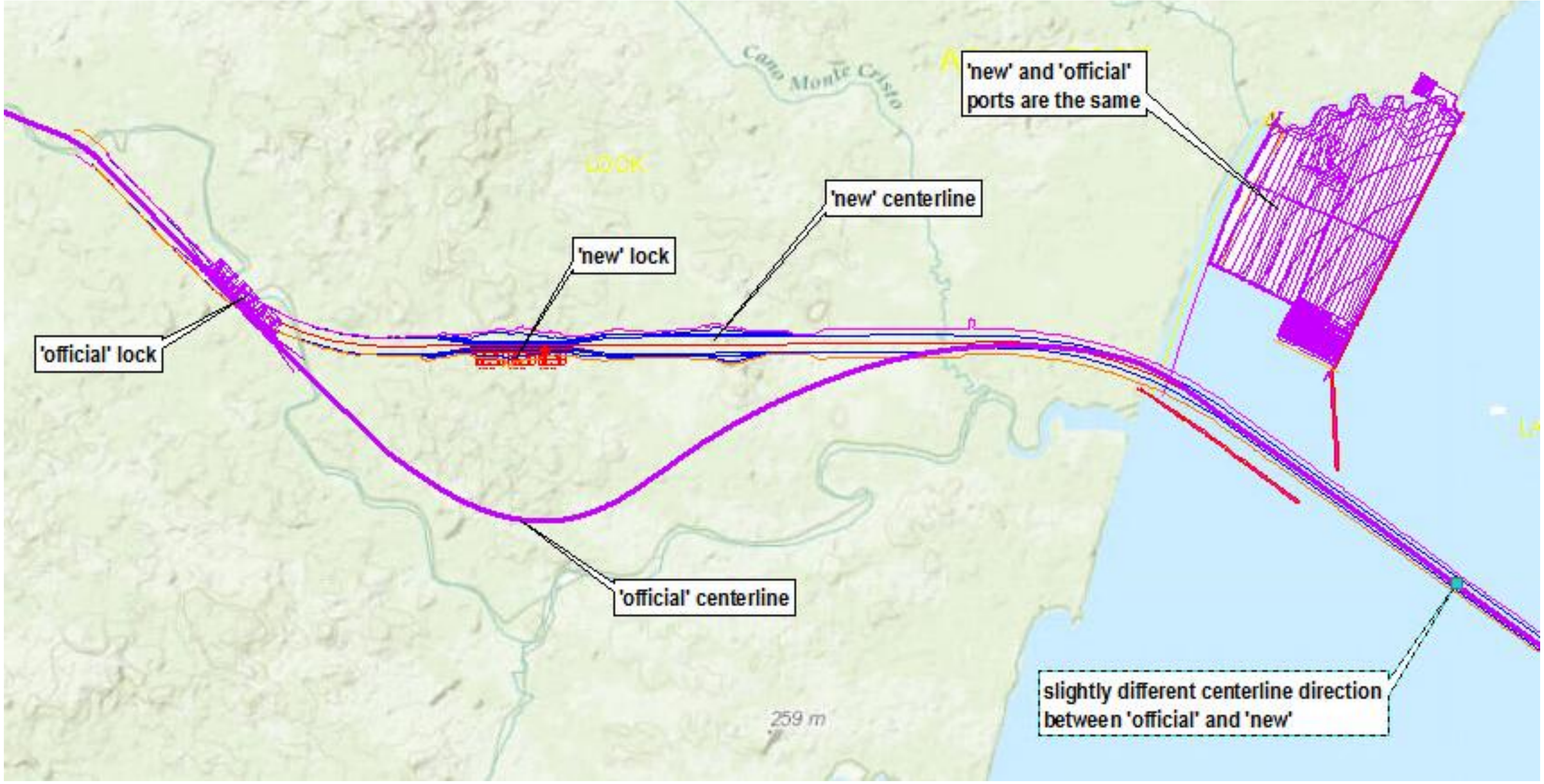
# Locks – Camilo Lock




- Two alternative locations being investigated
- Aiming to minimize environmental impact and increase safety

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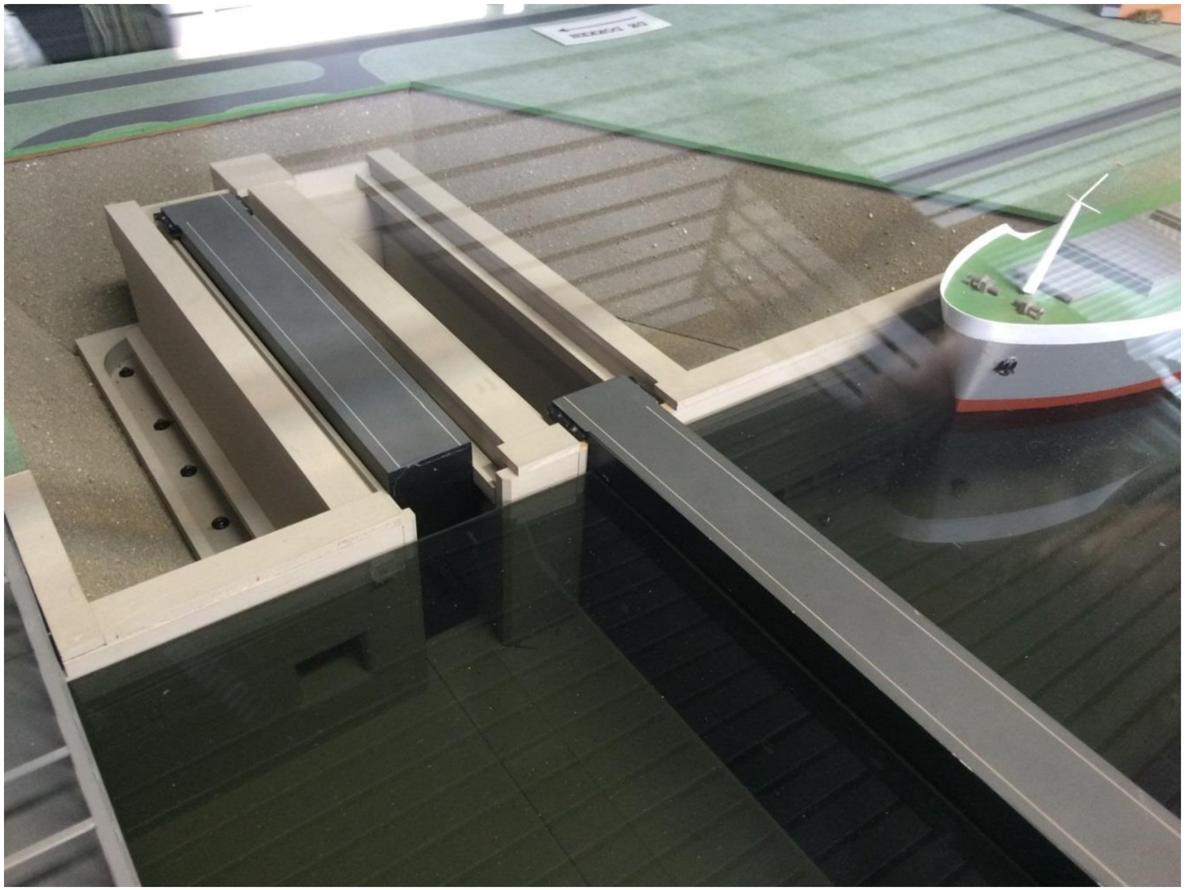
# Locks – Gate Design



- “Rolling Gates” selected for best security
- Double gates provide backup in event of ship collision
- Lock can be empty to allow maintenance

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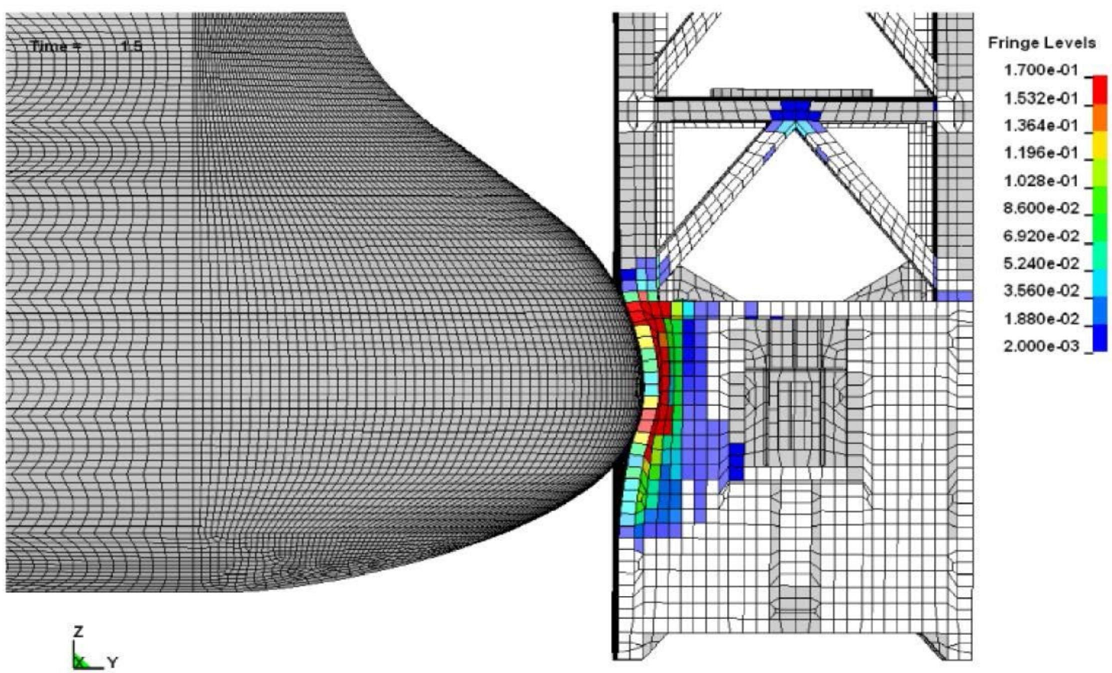
# Locks – Gate Design

Figure 6-6 Equivalent plastic strain [-] in the deformed area at t=1.500 s. Elements exceeding 17%strain are coloured red.




- Bulb-bow collision
- Gates designed to withstand ship impact
- But still have double gates for additional safety and availability

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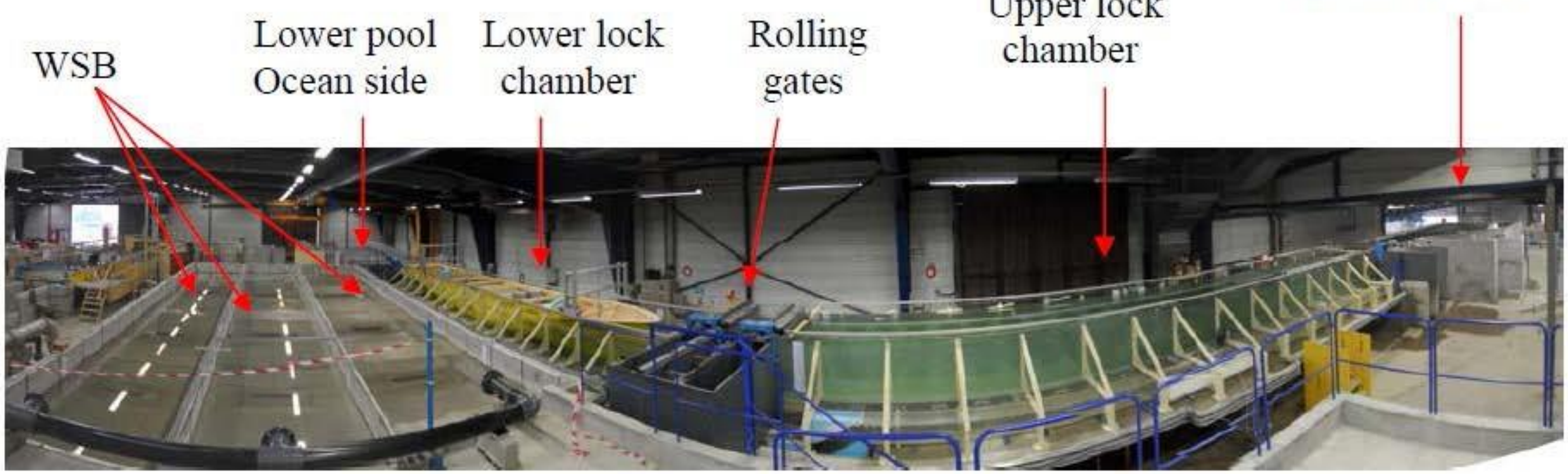
# Locks – Physical Modelling

Figure 1 gives an overview of the physical model:




- two (2) lock chambers, identified as upper & lower chambers,
- three (3) WSBs associated with the lower lock chamber,
- one (1) 250 m long fore bay (Gatun lake side),
- one (1) 400 m long tail bay (ocean side).
- all the elements (culverts, conduits, ports, valves, etc.) of the F/E system as proposed in the tender design,
- the double set of rolling gates and their recesses on every lock chamber.

Physical modelling used to confirm/support mathematical simulations

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# Hazardous Material Spill Risk

- Oil and toxic material leakage in the Lake requires contingency planning
- Predicable current flow in Lake Nicaragua assists containment and clean up

# Hazardous Material Spill – Risk Mitigation by Management

- Identify operation hazards
- Reduce hazard by inherent design
- Emergency stations at both sides of Lake to speed up recovery
- Well trained and equipped rescue teams
- Crises Management Plan with constant drills
- Enhance control and monitoring of high risk ships
- Right to reject ships not meeting our safety standards

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# Hazardous Material Spill – Risk Mitigation by Operation

- Quarantine Areas
- Buffer Zones
- Rapid Response Units
- Emergency Access Points
- Oil Leak Control
- Fire Fighting
- Special Security Force
- Disaster Warning System
- Safety Management System

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# Risk Based Asset Management System

- ISO55000 Asset Assurance Management Systems used
- Risk assessments applied from operation to design and construction to mitigate risks
- Most risks mitigated by inherent design with residual risks controlled by operation procedures
- Independent Verification & Validation process employed to ensure asset commission as designed
- Failsafe designs adopted for safety critical items
- Safety Case required for safety critical asset like the Lock
- Reliability Centred Maintenance adopted

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# Further Studies – Aerial Survey


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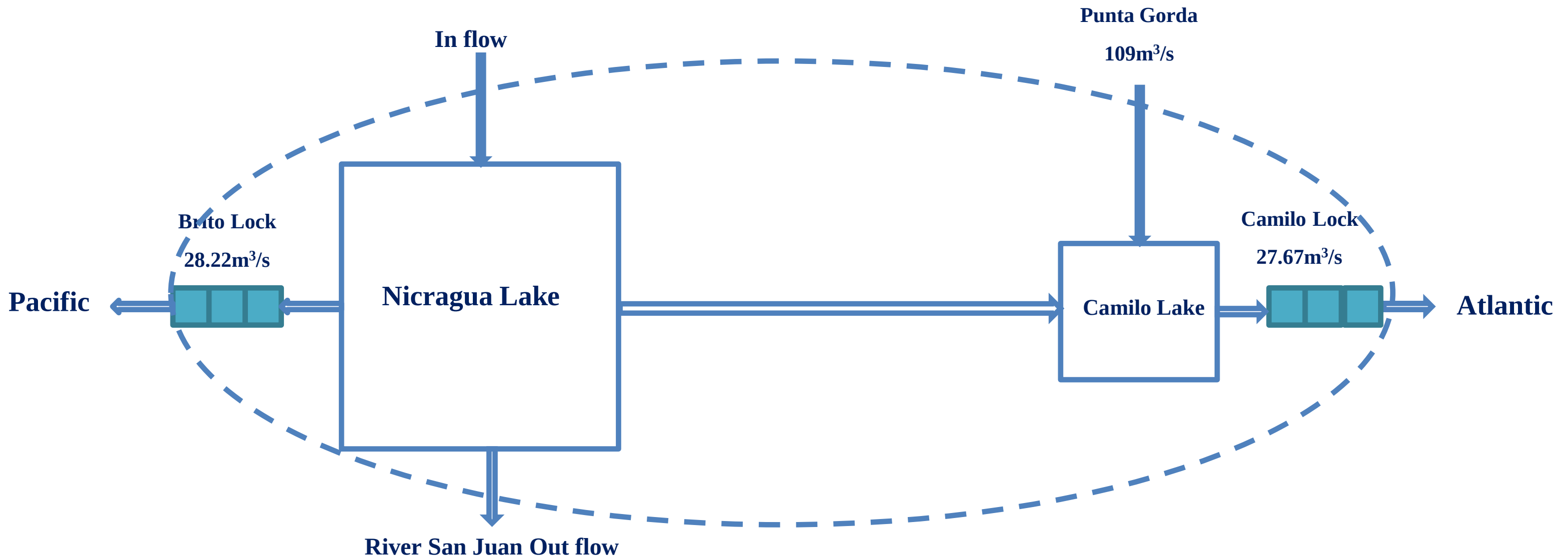
# Further Studies – Water Balance



# Further Studies – Salinity Management

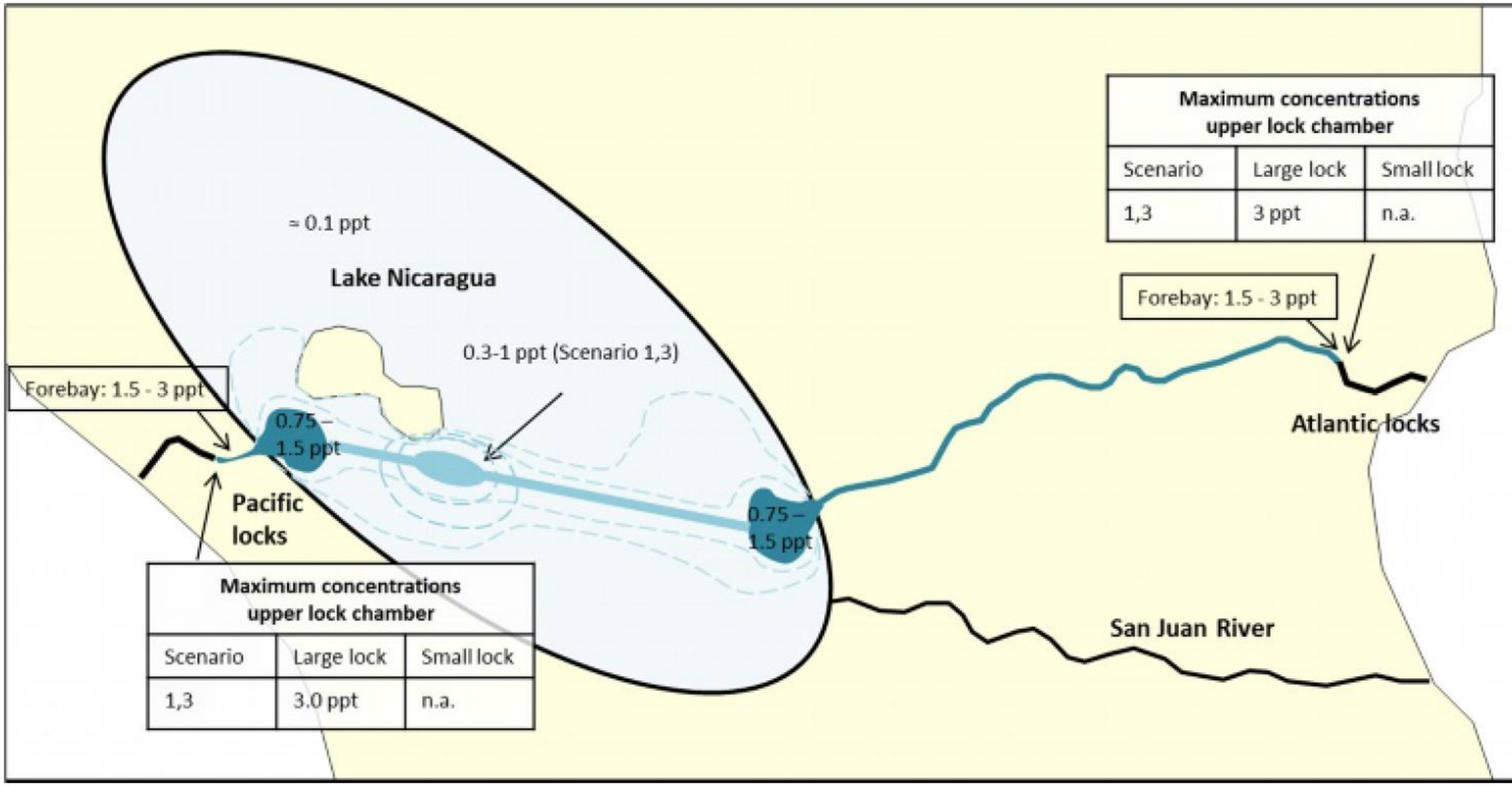



*Figure 2: sketch of indicative salt concentrations in LN.*

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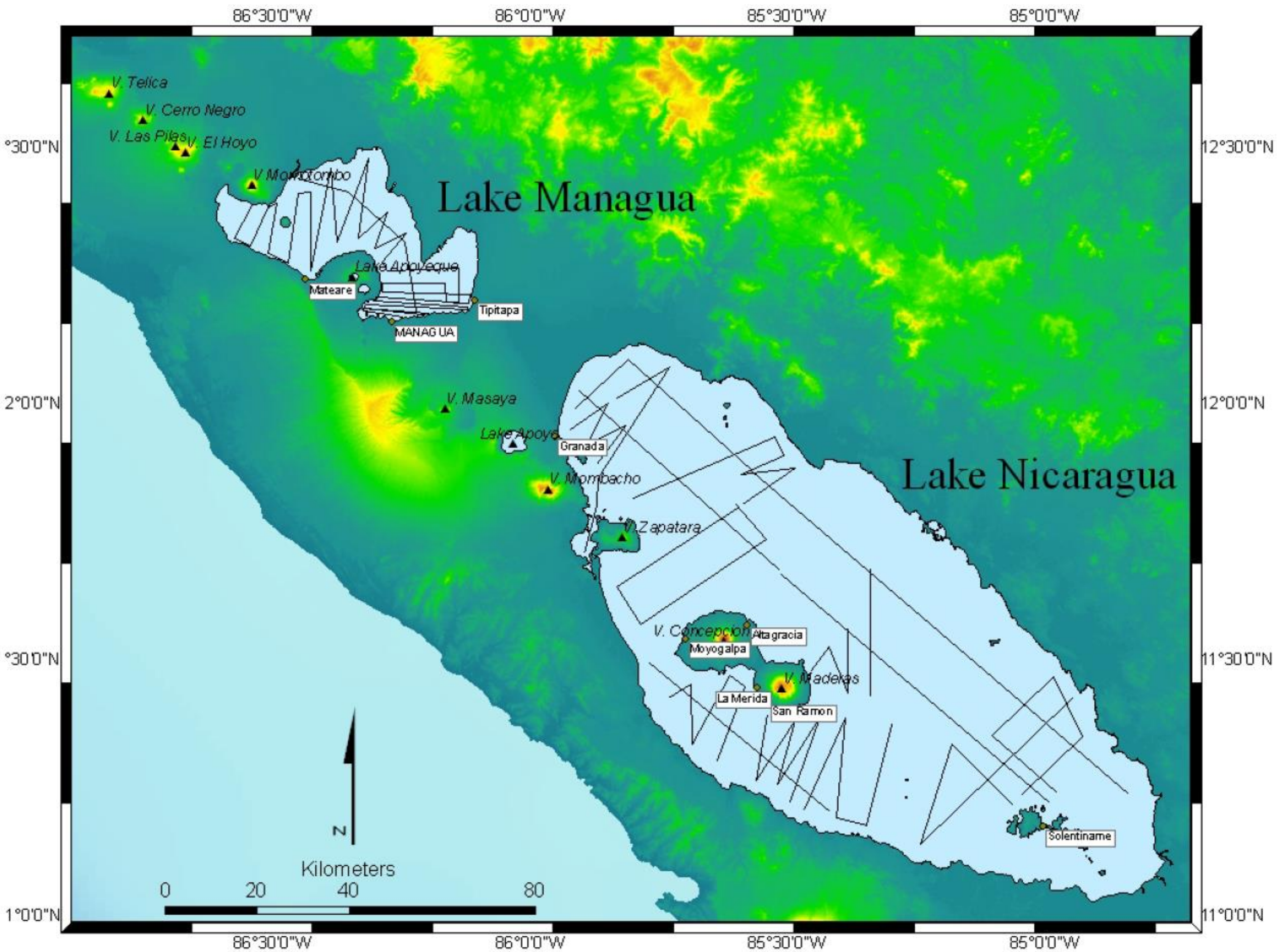
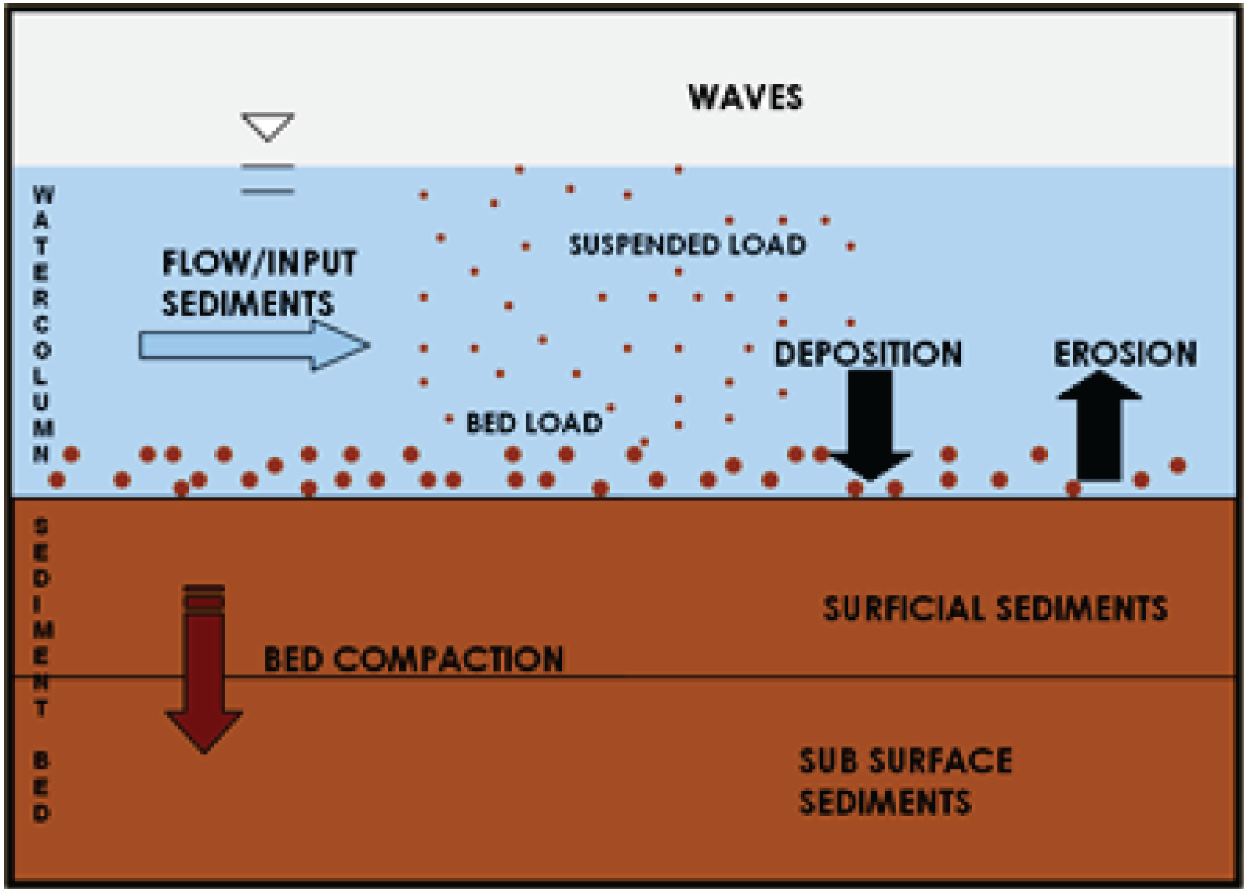
# Further Studies – Seismic



# Further Studies – Sedimentation

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# Thank You !


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