Limits to Growth defined by Water Resource, Waiheke Island Case Study

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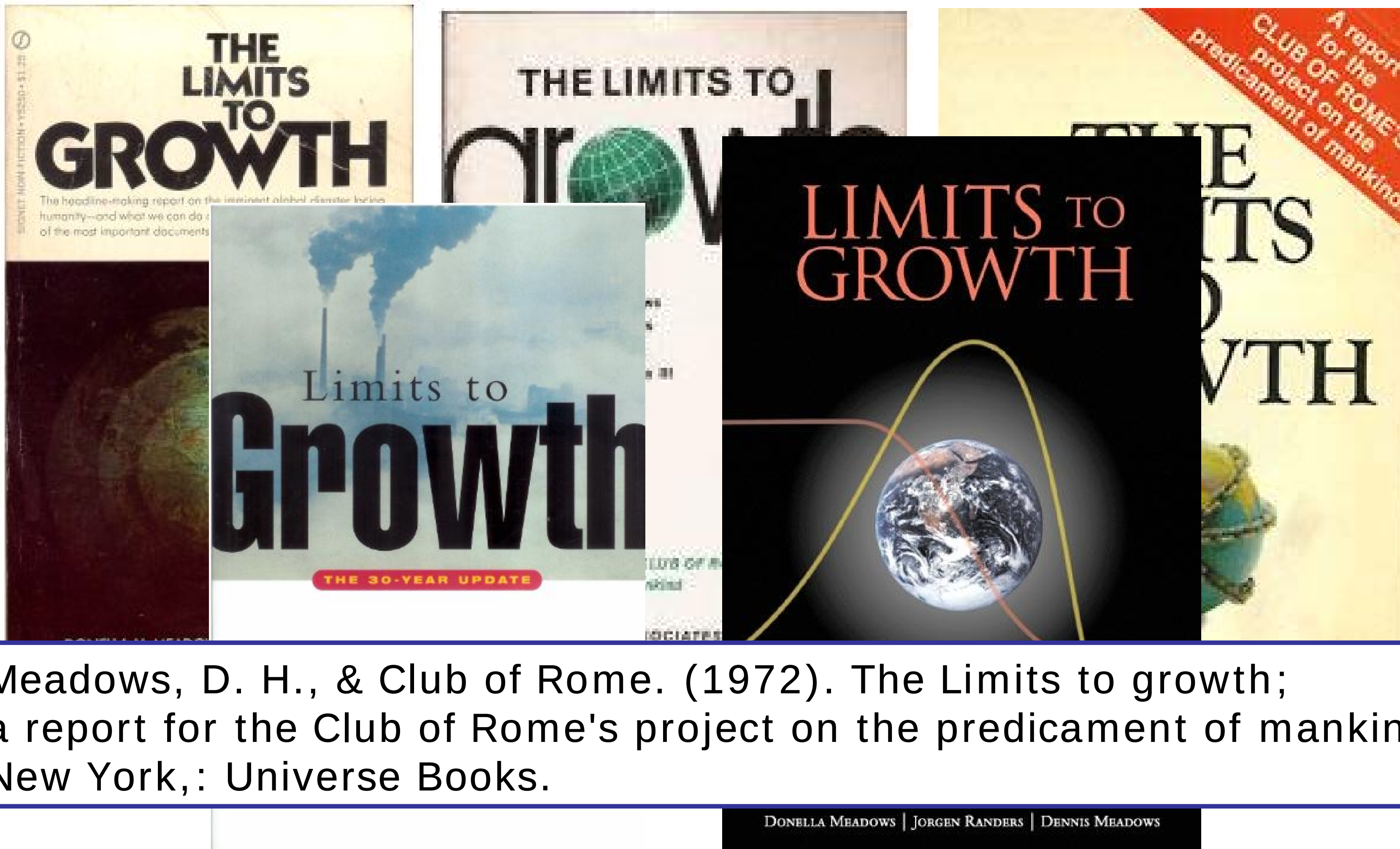
Limits to Growth

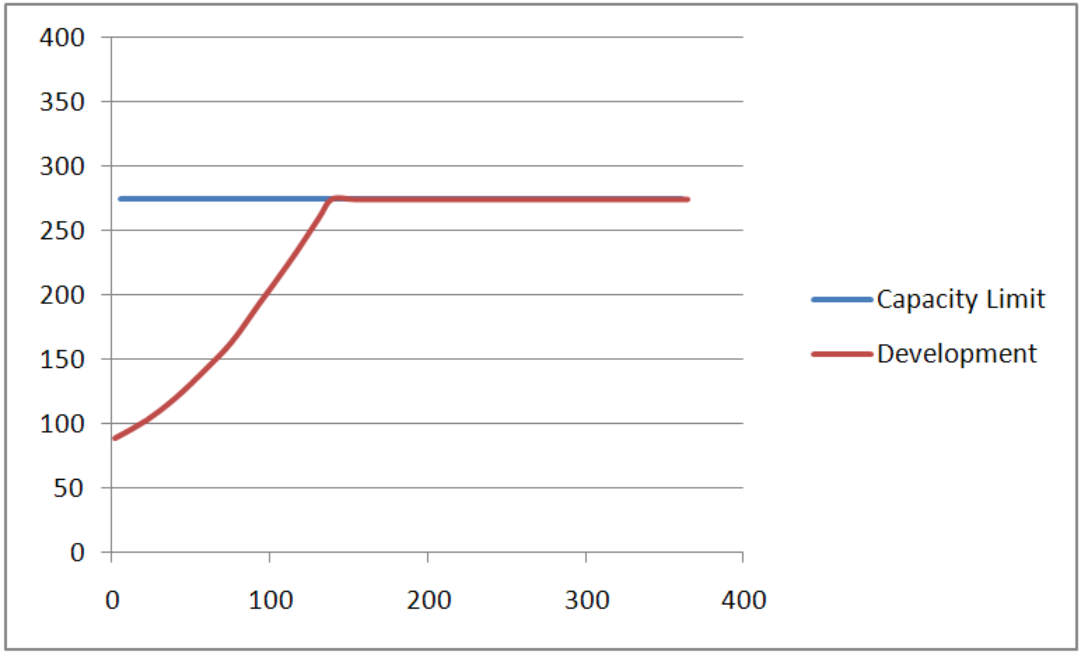


Meadows, D. H., & Club of Rome. (1972). The Limits to growth; a report for the Club of Rome's project on the predicament of mankind. New York,: Universe Books.

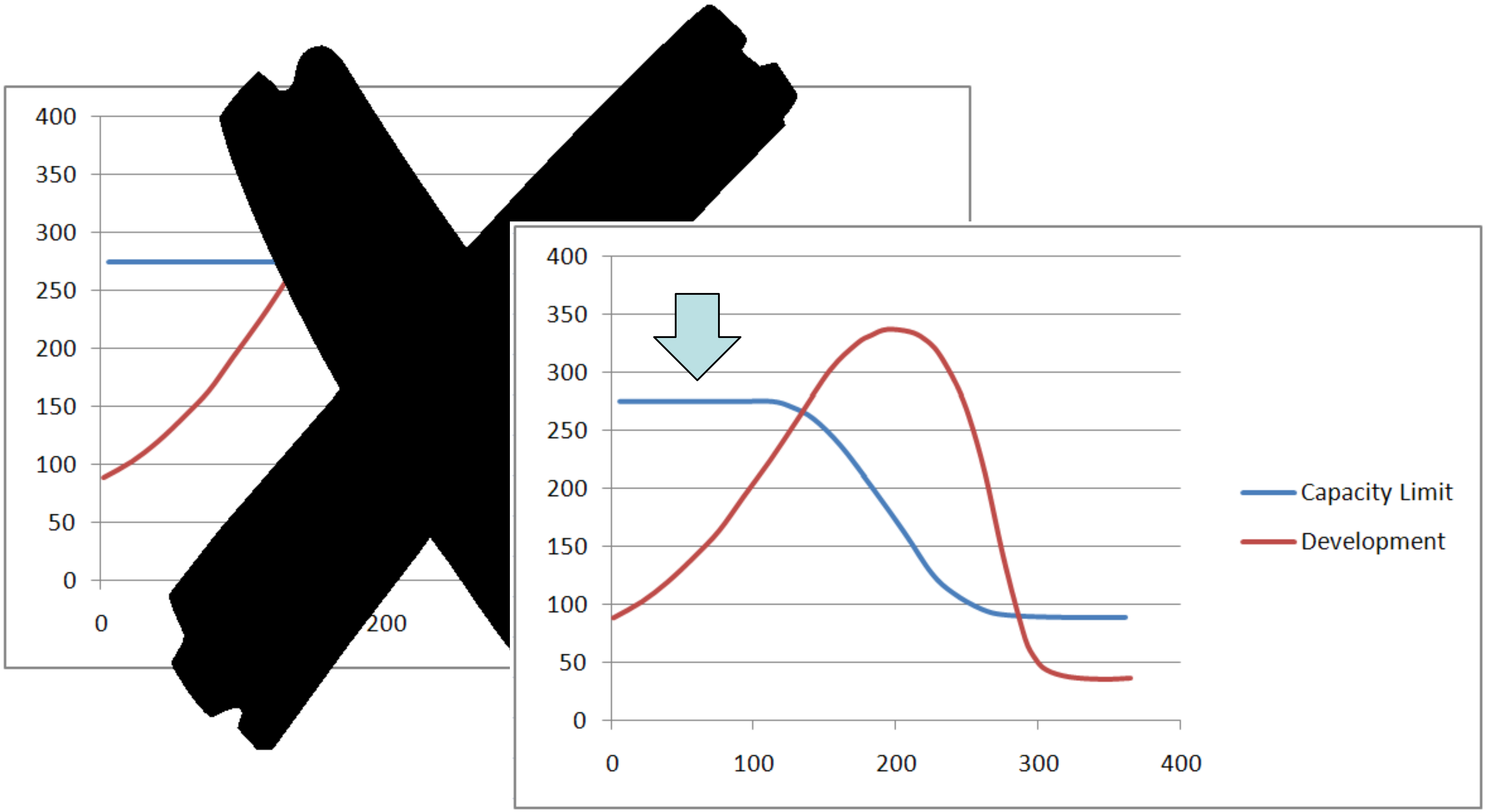
Limits to Growth Conceptual Findings

- Sustainability is primarily associated with the resource/pollution quantity or rate limits.
  - Environmental Provisions vs Human uptakes and emissions.
- Limits do not pose hard development blockade but forces human society to run at higher costs as the resource pools decline
  - Main cause of overshoot-collapse dynamics.

Limits to Growth Conceptual Findings



Limits to Growth Conceptual Findings



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Research Objective

- Estimate Population Limit that the **island** water supply capacity can sustainably accommodate.
- Given **Rainfall pattern**, Possible **Impervious Surface Area** used for Collection, **Aquifer Limit** on Pump, how many people can sustainably fitted on an island?
- Case Study of Waiheke Island (92km^2).

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Waiheke Island

Population 8,420

Household 3,470

Rainfall 1,200mm/yr

Area 92km^2

Wet April - Sept

Dry Oct - Mar

Seasonal Visitor 22,000

Res. Water use

140L/day/cap

Electrical Connection

No Water Main Con.

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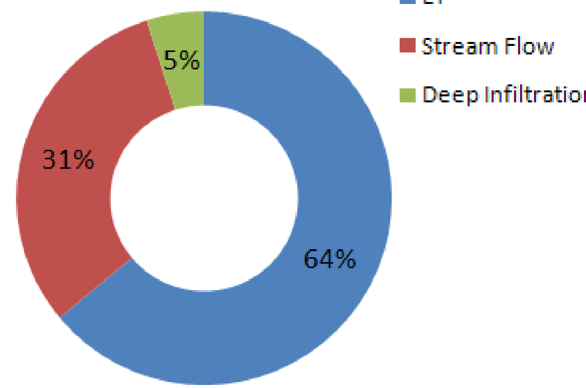
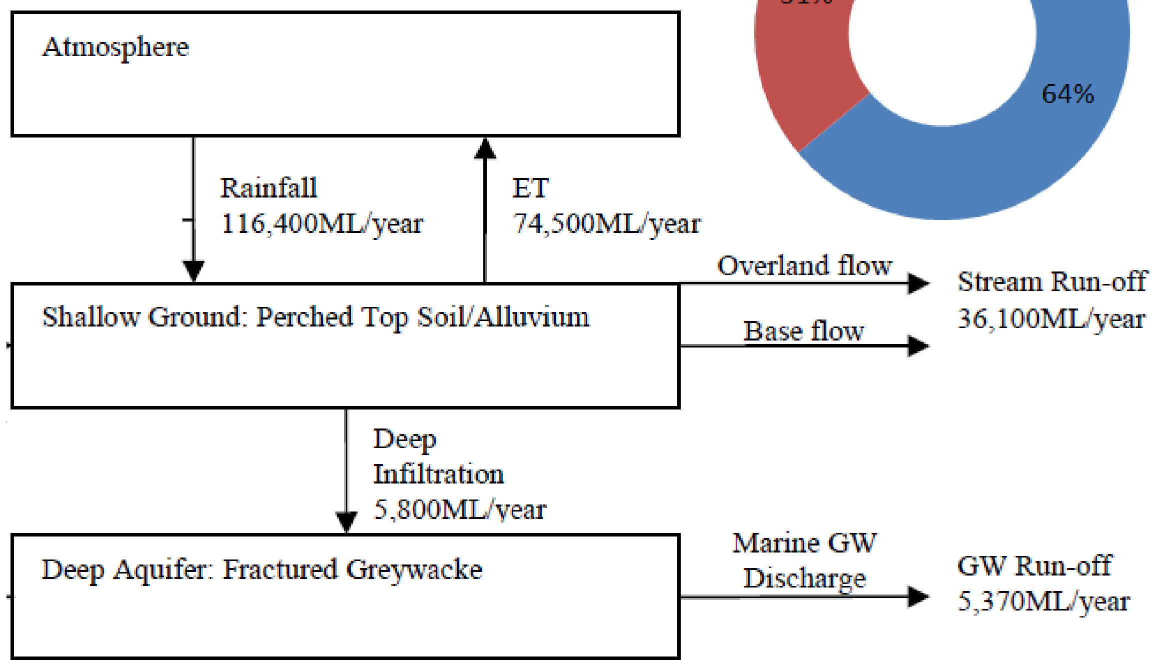
Waiheke Island Hydrology





Methodology

- Observations
  - Collection Capacity is the Primary Limit now.
  - Collection Capacity can expand through investments.
  - But collection capacity cannot exceed the sustainable capacity of the natural hydrology.
- Step 1: Build a Simulation calculating Supply Capacity.
- Step 2: Identify parameters defining Limits.
- Step 3: Build scenario by altering the parameters.
- Step 4: Apply Natural Limits to the parameters.

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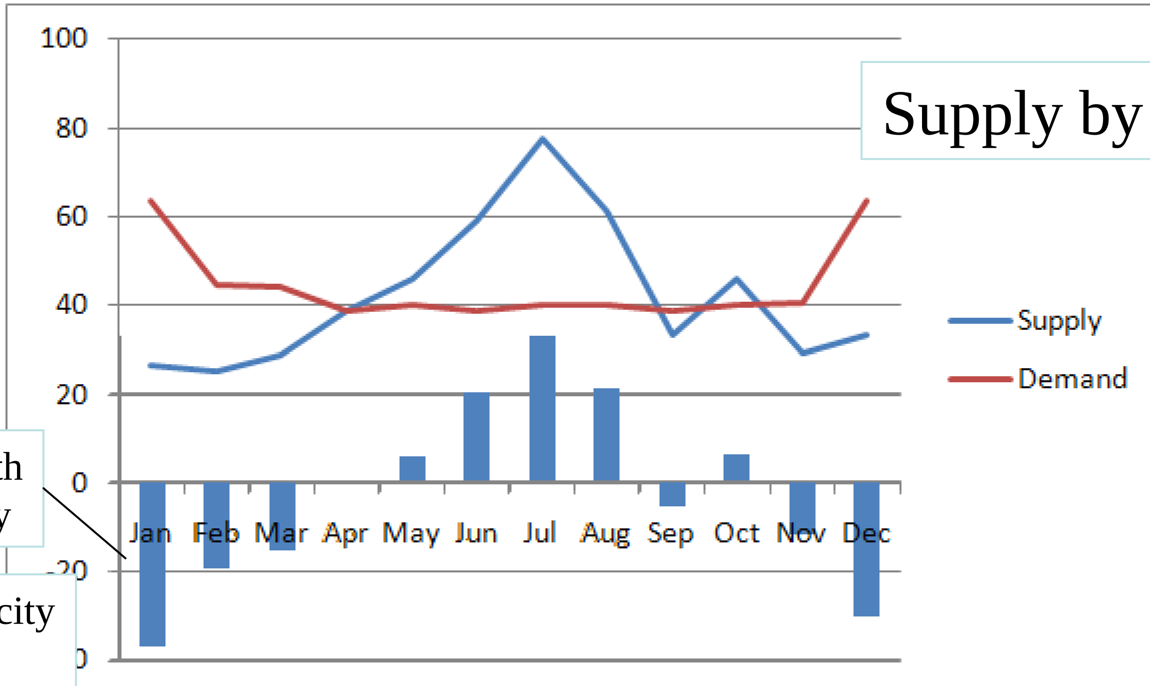
Step 1. Current Collection Capacity

- Roof-Rainwater Capacity
  - Roof Area x connection rate x rainfall x efficiency = 847,000m^2 x 80% x 1200mm/yr x 65% = **554ML/yr**
- Pump
  - Inferred from council consent database
  - **427ML/yr** = 1.17ML/day
- Stream Take Ignored
  - **0ML/yr**
- Island wide Demand
  - **533ML/yr**
- **Annual Supply Capacity > Annual Demand**
- **554 + 427 > 533**

Step 1. Rain Harvest Capacity



Supply by Roof Harvest only

40ML/month
=1.3ML/day

Pump Capacity
=427ML/yr
=1.17ML/day

Dry Summer | Wet Winter | Dry Summer

Roof Supply
554ML/yr

Demand
533ML/yr

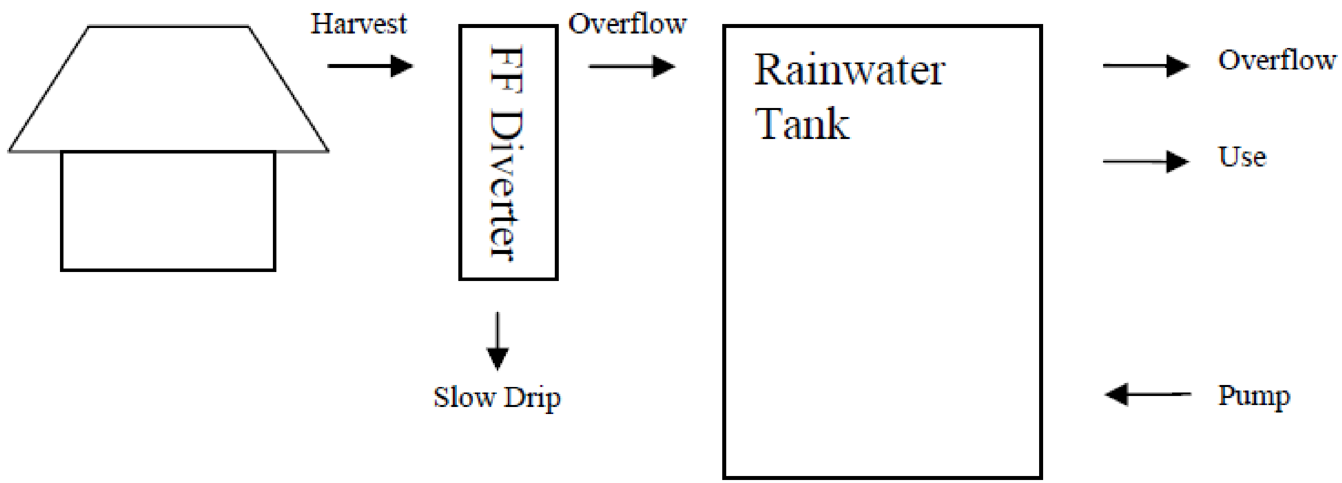
Winter Excess
123ML/yr

Summer Deficit
102ML/yr

Needs simulation if enough wet water can successfully cover summer demand

Step 1. Rainwater Simulation

- Daily-step Two stage storage rainwater harvest system was simulated using Excel.
- Island Roof Area, Storages, Pumps are lumped.



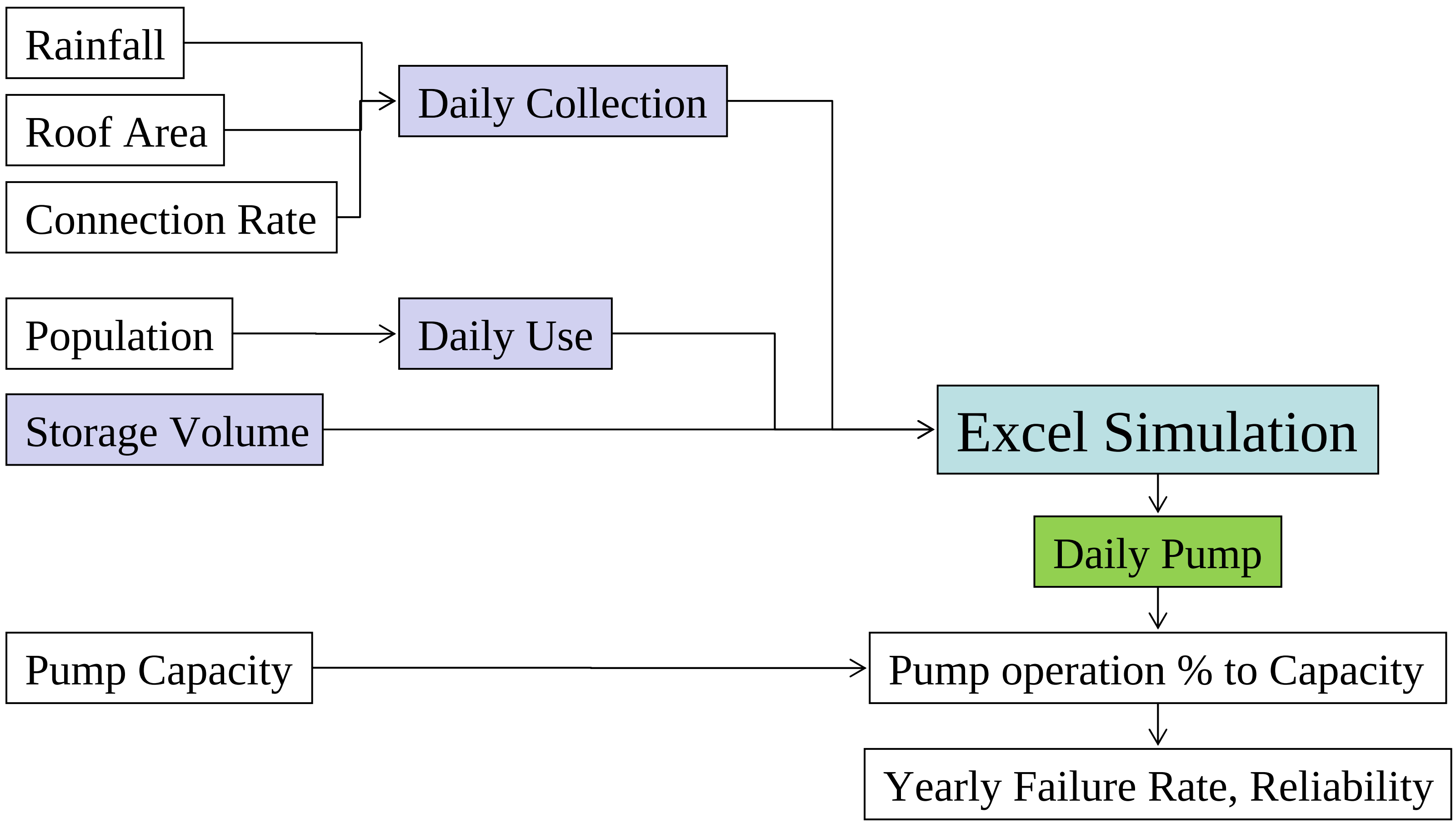
Step 1. Rainwater Simulation

	AUF	AUG	AUH	AUI	AUJ	AUK	AUL	AUM	AUN	AUO	AUP	AUQ	AUR	AUS	AUT	AUU
22																
23																
24	Month	Day 28	2009	Collected	FFD	FFD drip	FFD over	Tank	Tank over	Use	Tank Test	Pump		Month	Day 28	2
25	Last year Carry		0	0	0.07	0.07	0	44.11561	0	2.051762	42.06384	0		Last year Carry		
26	1	1	1.5	1.017	0.14	0.07	0.877	42.94084	0	2.051762	40.88908	0		1	1	
27		2	0	0	0.07	0.07	0	40.88908	0	2.051762	38.83732	0			2	
28		3	1.5	1.017	0.14	0.07	0.877	39.71432	0	2.051762	37.66256	0			3	
29		4	8	5.424	0.14	0.07	5.354	43.01656	0	2.051762	40.9648	0			4	
30		5	0	0	0.07	0.07	0	40.9648	0	2.051762	38.91304	0			5	
31		6	0	0	0	0	0	38.91304	0	2.051762	36.86127	0			6	
32		7	0	0	0	0	0	36.86127	0	2.051762	34.80951	0			7	
33		8	0	0	0	0	0	34.80951	0	2.051762	32.75775	0			8	
34		9	0	0	0	0	0	32.75775	0	2.051762	30.70599	0			9	
35		10	0	0	0	0	0	30.70599	0	2.051762	28.65423	0			10	
36		11	9	6.102	0.14	0.07	5.962	34.61623	0	2.051762	32.56446	0			11	
37		12	0	0	0.07	0.07	0	32.56446	0	2.051762	30.5127	0			12	
38		13	0	0	0	0	0	30.5127	0	2.051762	28.46094	0			13	
39		14	0	0	0	0	0	28.46094	0	2.051762	26.40918	0			14	
40		15	0	0	0	0	0	26.40918	0	2.051762	24.35742	0			15	
41		16	0	0	0	0	0	24.35742	0	2.051762	22.30566	0			16	
42		17	0	0	0	0	0	22.30566	0	2.051762	20.25389	0			17	
43		18	7.3	4.9494	0.14	0.07	4.8094	25.06329	0	2.051762	23.01153	0			18	
44		19	2.9	1.9662	0.14	0.07	1.8962	24.90773	0	2.051762	22.85597	0			19	
45		20	0	0	0.07	0.07	0	22.85597	0	2.051762	20.80421	0			20	
46		21	0.6	0.4068	0.14	0.07	0.2668	21.07101	0	2.051762	19.01925	0			21	
47		22	0	0	0.07	0.07	0	19.01925	0	2.051762	16.96748	0			22	
48		23	0	0	0	0	0	16.96748	0	2.051762	14.91572	0			23	
49		24	0	0	0	0	0	14.91572	0	2.051762	12.86396	0			24	
50		25	0	0	0	0	0	12.86396	0	2.051762	10.8122	0			25	
51		26	0	0	0	0	0	10.8122	0	2.051762	8.760437	0			26	
52		27	0	0	0	0	0	8.760437	0	2.051762	6.708675	0			27	
53		28	0	0	0	0	0	6.708675	0	2.051762	4.656913	0			28	
54		29	0	0	0	0	0	4.656913	0	2.051762	2.605151	0			29	
55		30	0	0	0	0	0	2.605151	0	2.051762	0.55339	0			30	
56		31	0	0	0	0	0	0.55339	0	2.051762	-1.49837	1.498372			31	

Stats Summary | Raw 95 years | Use Schedule | 95-year sim | Population Limit

Ready 100%

Step 2. Parameter Relation



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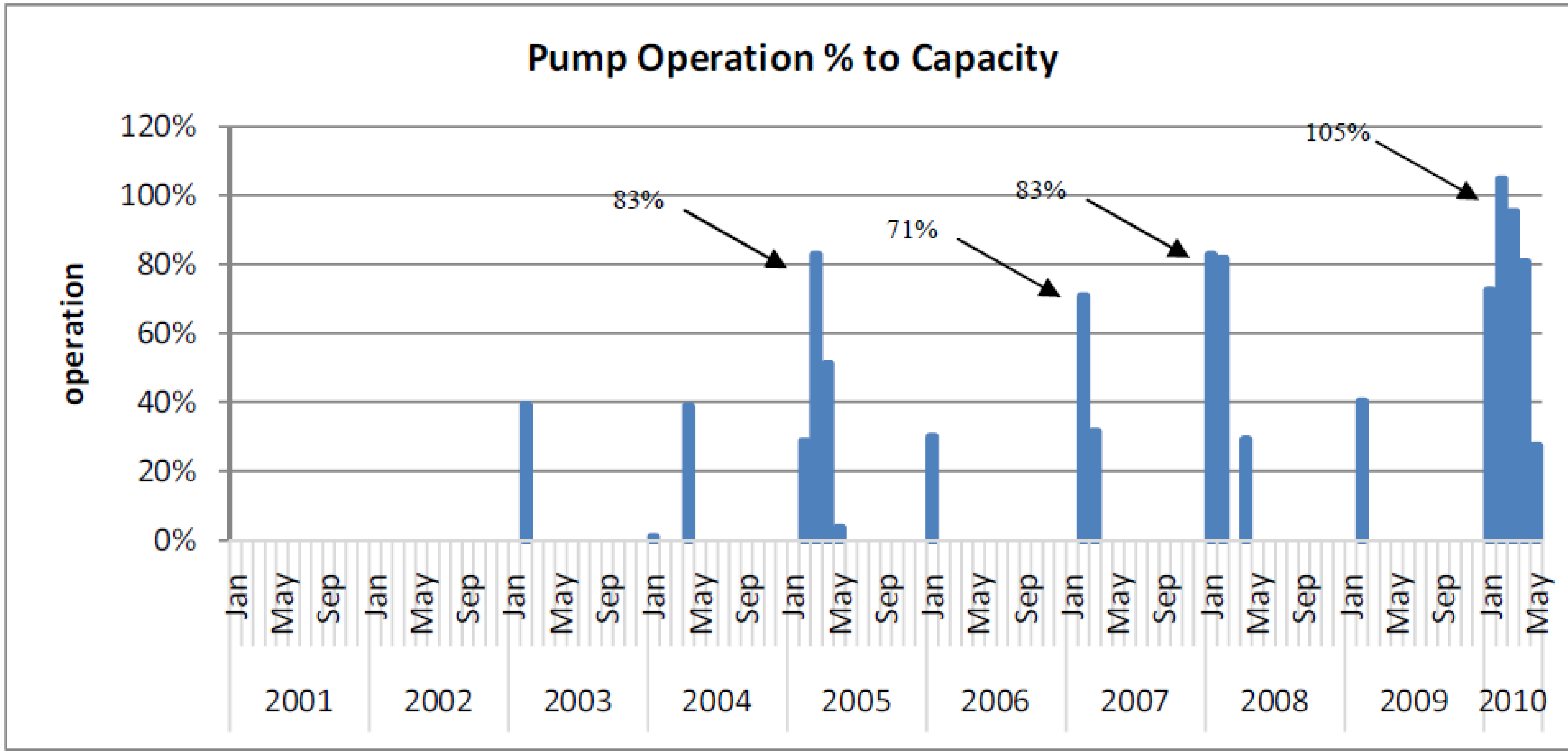
Step 1. Rainwater Simulation Results



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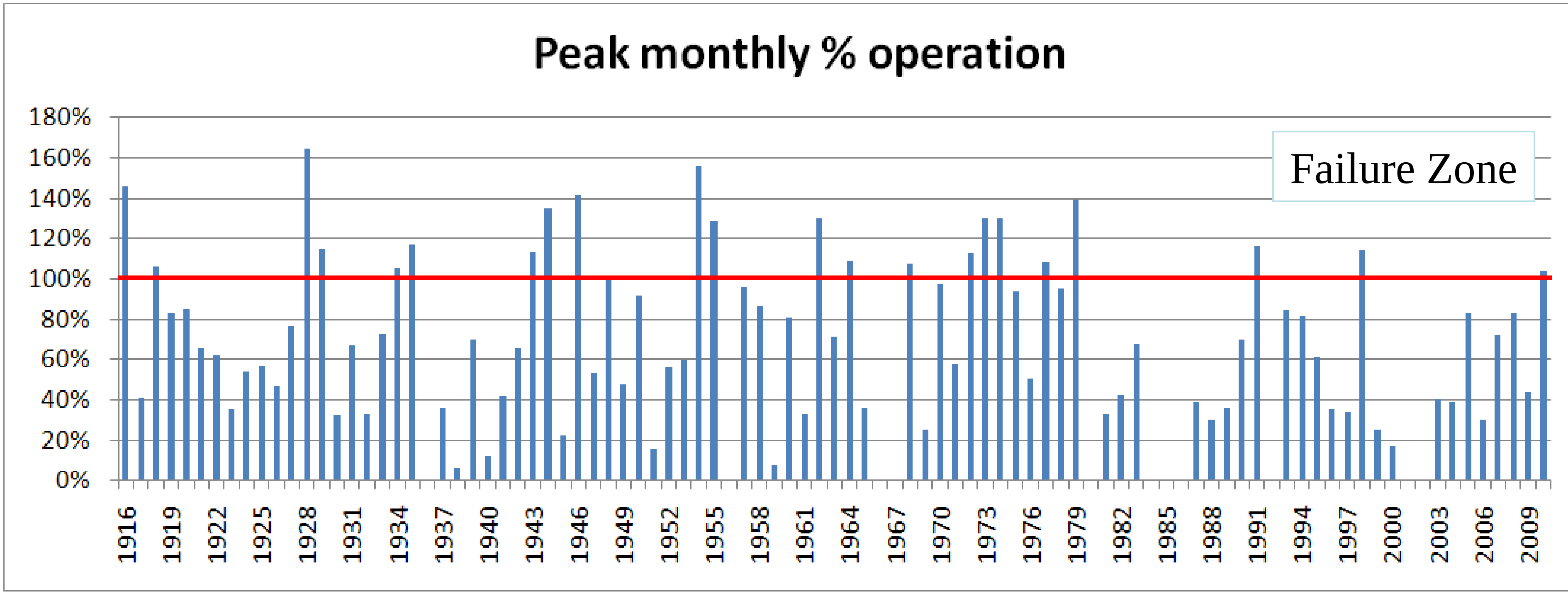
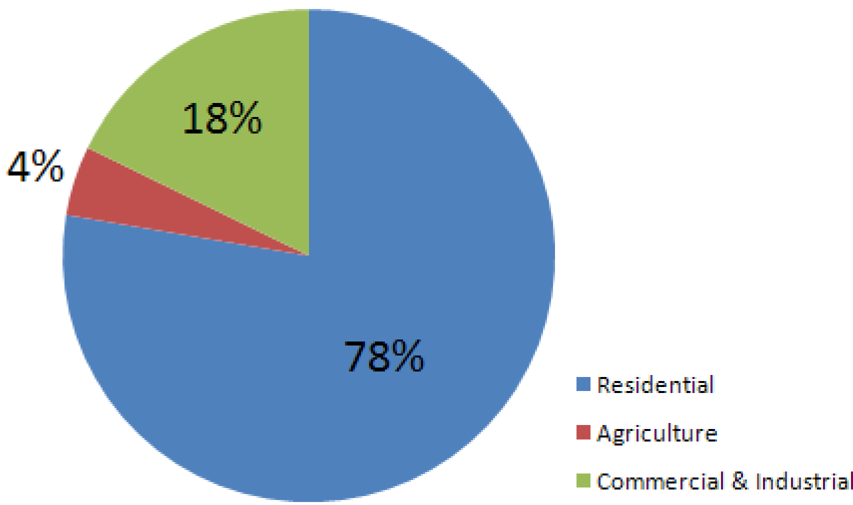


Current system cannot sustain 8,420 residents + 22,000 visitors with the adequate supply reliability. What is sustainable Population with current collection capacity?

Step 3. Population Effect on Use

Annual Water Use Share



Residential Use
- Proportional to Population

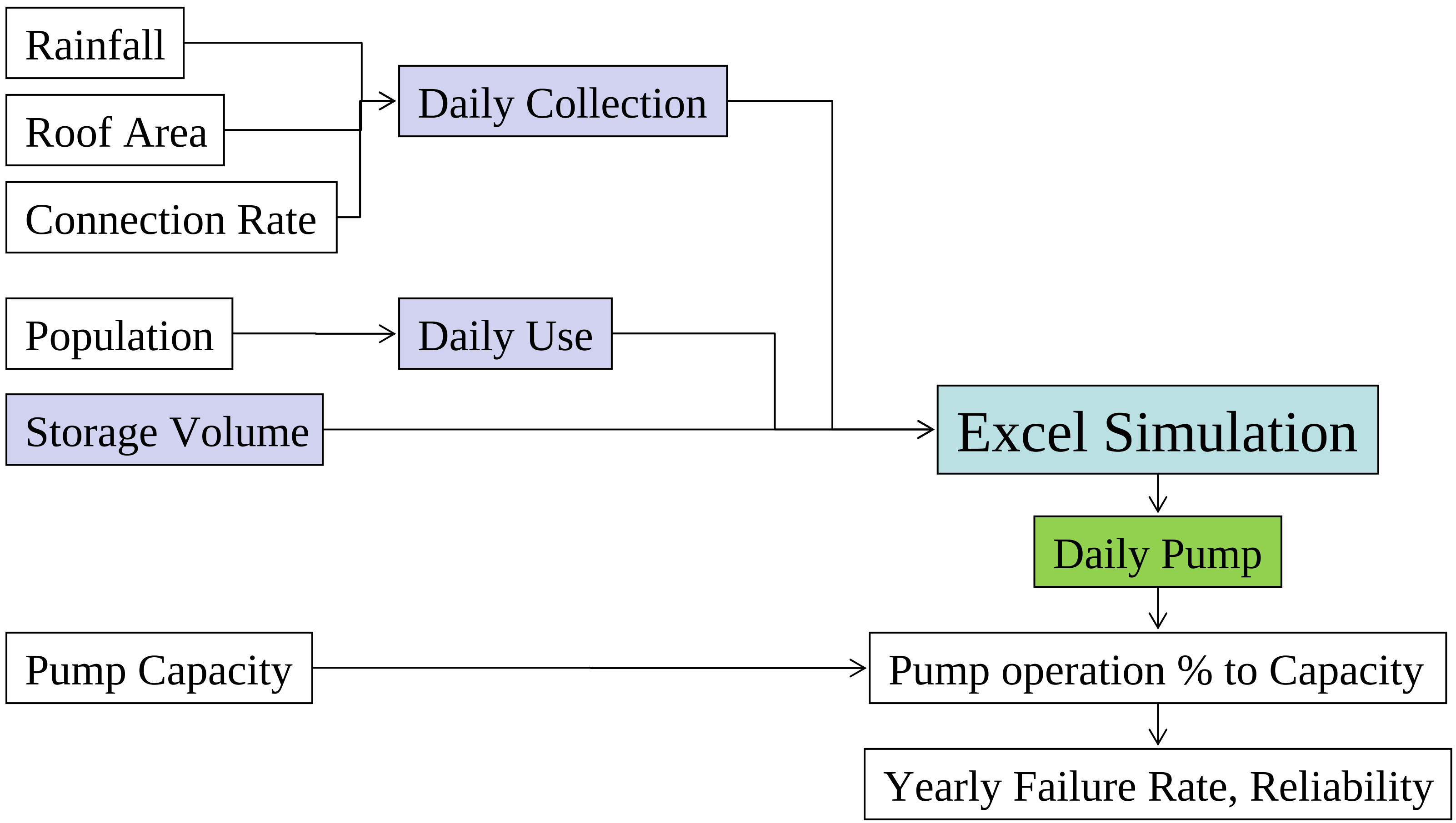
Agricultural Use
- Non-reactive to Population

Commercial/Industrial
- 51% of it is proportional to Population

Adjust the daily use quantity scenario reflecting this relation until 5% fail rate has been achieved in 95-year simulation.

Result: **6,730** can be supplied with 95% reliability.

Step 2. Parameter Relation



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Step 3. Some Development Scenarios

Upgrades	Sustainable Population
Base Line	6,730
Free Emergency Supply	
Running Inactive Bore	9,550
Rain Tank Installations	
2x RainTank	8,480
2x RainTank + Inactive Bore	11,040
3x RainTank	10,430
3x RainTank + Inactive Bore	11,870
Bore Explorations	
2x Bores	12,050
3x Bores	20,120
Impervious Area Connections	
2x Roof	11,850
3x Roof	17,700

Changed the parameters then adjusted population till 95% reliability was achieved.

Step 4. Max Development Scenarios

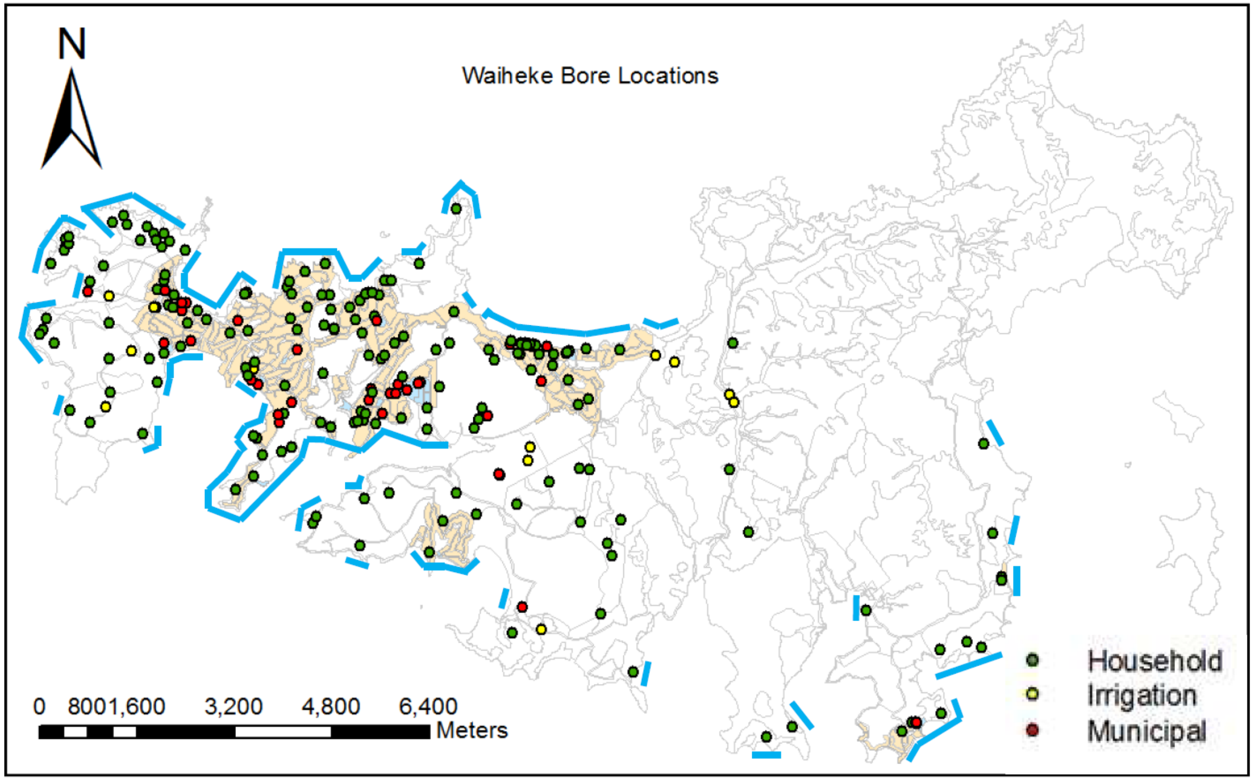
Upgrades	Sustainable Population
Expansive Limits	
50% Max Roof	25,990
50% Max Bore	41,360
50% Max Roof + 50% Max Bore	48,960
Max Roof	52,220
Max Bore	87,290
Max Bore + Max Roof	100,640
Max Bore + Max Roof + 2x RainTank	108,450
Max Bore + Max Roof + 3x RainTank	115,530
With Water Saving Fixtures	
Base Line	8,200
Running Inactive Bore	11,630
2x RainTank	10,270
Max Bore + Max Roof + 3x RainTank	140,500

Estimation Details of Max Roof and Max Bores are found in the Proceeding.

Conclusions and Recommendation

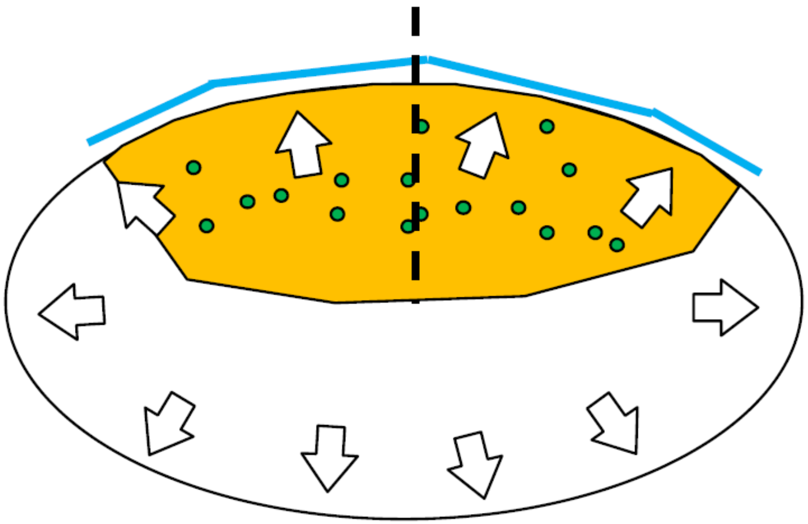
- Simple Roof-Harvest-Pump Model is an effective tool in estimating maximum sustainable population on an island.
- Current Waiheke Island Sustainable Capacity of Water Supply is 6,370. Environmental Limit of maximum Population is 100,000~140,000 with optimal distribution of pumps around the island and with intense development centre used to capture rainfalls.
- Shortcoming
  - Only considers traditional way of collecting and using water.
  - Consideration for WSUD, water reuse, artificial recharge in estimating sustainable population is recommended in future projects.

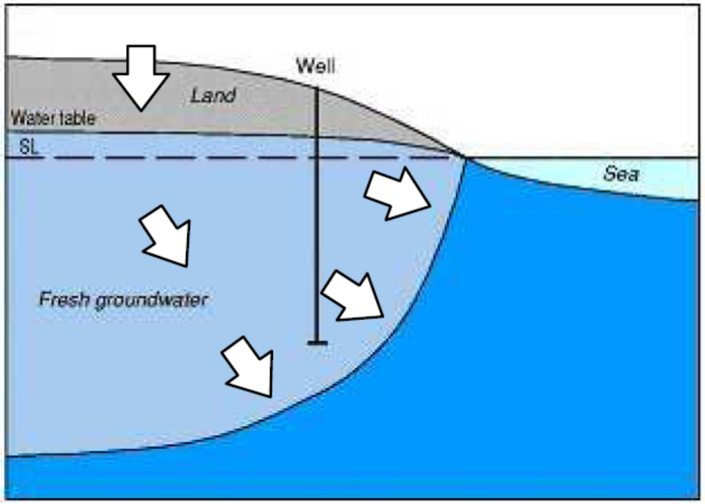
Appendix. Pump Bore Locations



MUL covers most of "flat" areas suitable for urban developments. Bore constructions and delivery must be placed to meet max dev.

Appendix. Pump Limit by Salt water Intrusion





Hypothetical Island GW flow: Horizontal, Vertical Cut.
Hydraulic Push is necessary to keep geometry of freshwater lens.
Nominal Value = 15% of Deep Recharge should be left for the push.