URANIUM HEAP LEACHING GAINING POPULARITY

By

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Presented by

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INTRODUCTION

- Initially uranium heap leaching operations tended to be satellites to conventional agitated acid leaching plants.
- Typically, solution from conventional circuit containing some ferric iron is fortified with acid then applied to the heaps. Resulting solution is processed through the main plant.
- However, stand alone heap leaching has been practiced in Spain, Brazil, Argentina and China.
- Recoveries typically in the 50-80% range.

INTRODUCTION (CONT.)

- Acid leach used to date and is being considered for a number of current projects.
- Alkaline heap leaching has been tested in the past, and is currently being commercialized.
- Generally, heap leaching has been limited to low grade ores, below 0.1% U_3O_8.
- ROM leaching can considered for very low grade ores.
- Permanent or on-off pad systems can be used

INTRODUCTION (CONT.)

- Heap bioleaching can be applied to sulphidic ores. In this case, the heaps are aerated to promote bacterial action, and no other oxidant would be added. Acid is generated in the heaps, thus reducing or eliminating acid make-up.

- Bacterial heap leaching of pyritic uranium ores was first applied at the Urgeirica plant in Portugal (now closed) after leaching of the stockpiles by rain water was observed. It has also been more recently applied in China.

ADVANTAGES OF HEAP LEACHING

- Low capex and opex.
- Elimination of grinding and solid/liquid separation.
- No crushing if run-of-mine ore treated.
- No tailings dam.

DISADVANTAGES

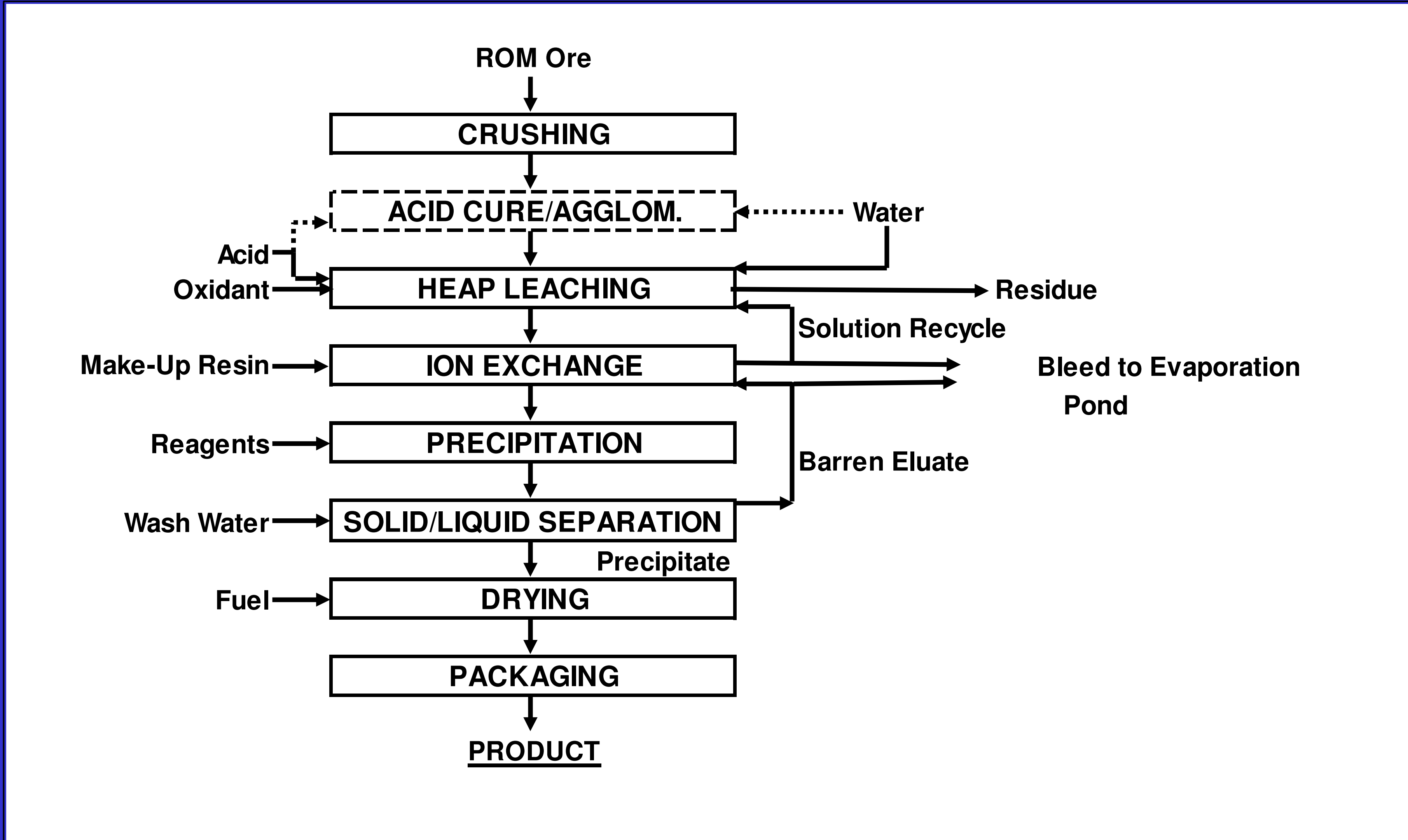
- Recovery is generally lower than agitated leaching.
- Leach cycle time is much longer.
- Lengthy testwork program.
- Large quantity of drill core needed for testwork.
- Ramp-up time is generally lengthy.
- Needs suitable terrain.
- Large footprint.
- Long term closure issues, especially if sulphides present.
- Could be a major environmental issue for cyclone prone locations.

URANIUM HEAP LEACHING FLOWSHEET DEVELOPMENT

Factors include:

- Ore physical and mineralogical characteristics – acid consumers, sulphides, clays, impurities, clays.
- Testwork results.
- Reagent supply logistics.
- Possible by-products or co-products.
- Skill level of potential work force.
- Industry practice.
- Site conditions, environmental requirements, project life, site water quality (especially chloride content).
- Risk minimization.
- Decommissioning issues.

TYPICAL URANIUM ACID HEAP LEACHING FLOWSHEET



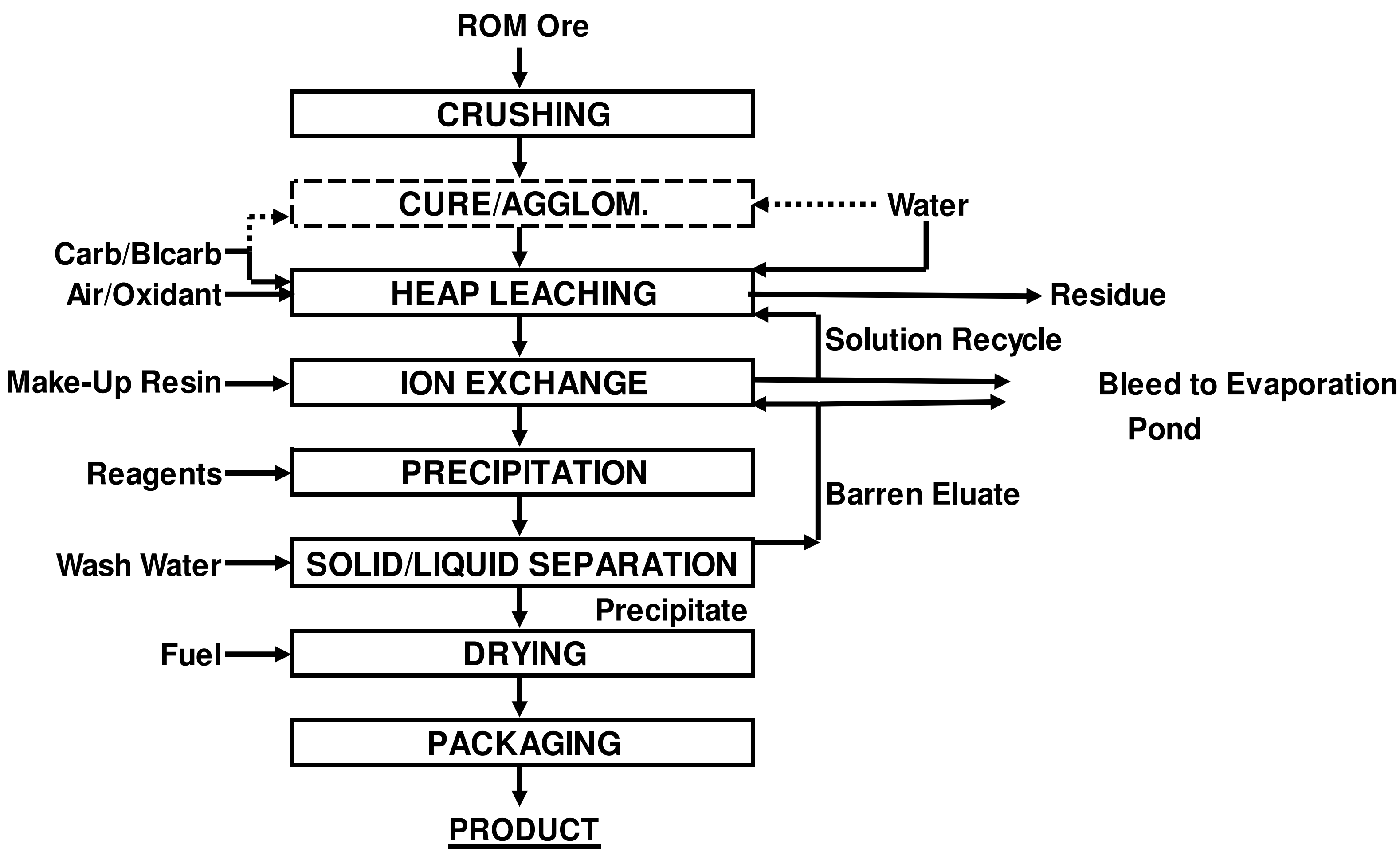
ACID HEAP LEACHING FLOWSHEET (CONT.)

- A strong acid agglomeration and curing step can be incorporated to improve percolation and increase initial leach kinetics.
- The solution grade can be built up by solution recirculation or staged countercurrent heaps.
- Oxidant addition depends on the ore type.
- Aeration could be considered, especially for sulphidic ores in which case acid is generated in the heaps, thus reducing or eliminating or reducing acid make-up.

ACID HEAP LEACHING FLOWSHEET (CONT.)

- Recovery method depends on solution concentration and type and level of impurities.
- SX favoured for higher grade solutions.
- IX for more dilute solutions
- A number of alternative SX stripping, IX elution and product recovery routes are available.

TYPICAL URANIUM CARBONATE HEAP LEACHING FLOWSHEET



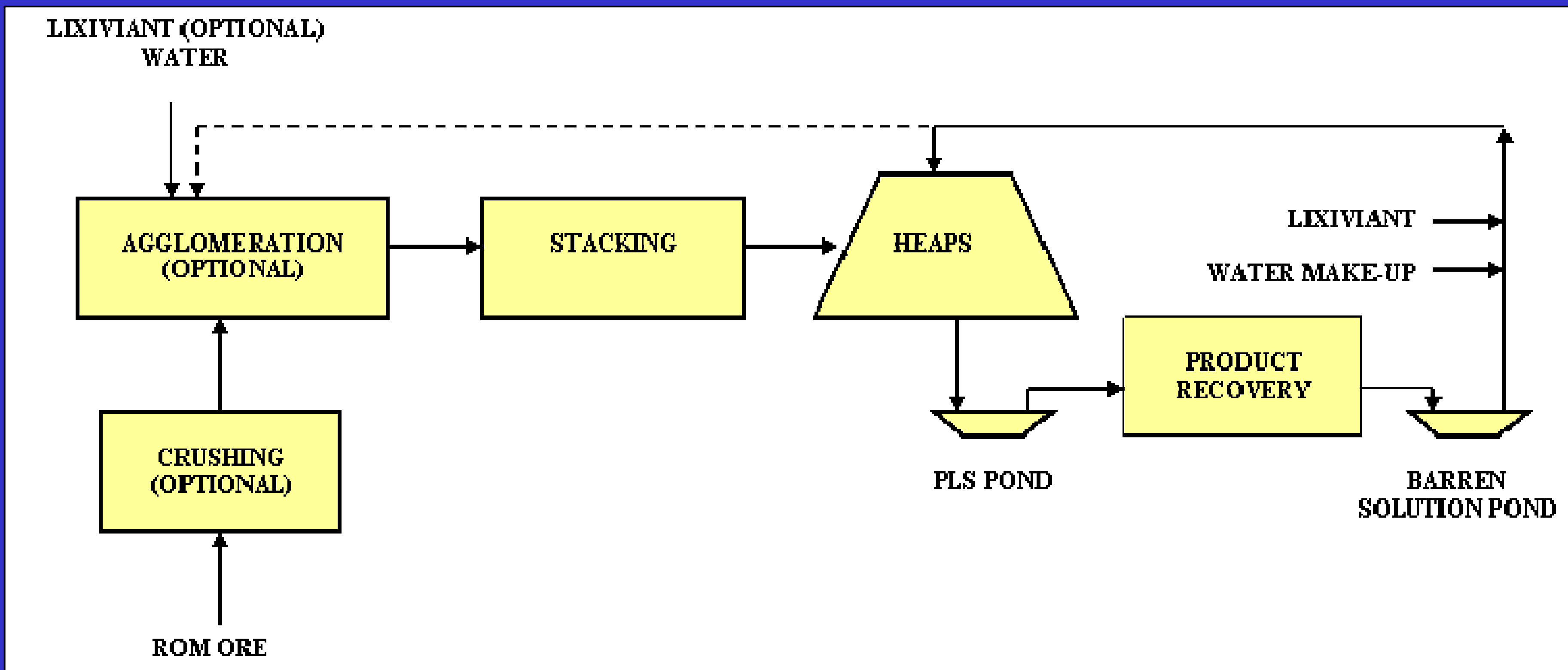
CARBONATE HEAP LEACHING FLOWSHEET (CONT.)

- Leach solution grade can be built up by solution recirculation or staged countercurrent heaps.
- Oxidation requirement will depends on the ore type. If needed, aeration could be considered.
- Agglomeration with lime or cement may be required for ores with high clay content.
- Could consider cure with strong carbonate solution to enhance initial leach kinetics.

CARBONATE HEAP LEACHING FLOWSHEET (CONT.)

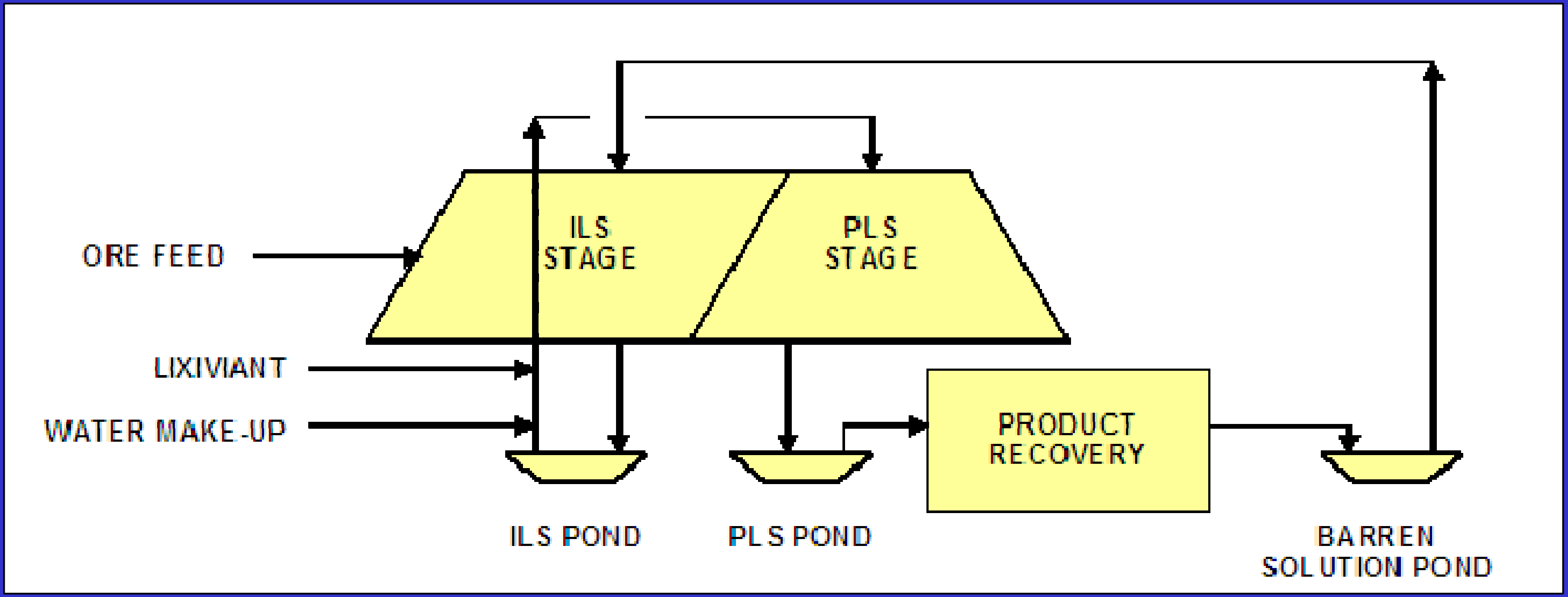
- Recovery method typically IX followed by precipitation, dewatering and drying.
- The presence of vanadium may require a uranium/vanadium separation step.
- SX not applicable.

TYPICAL HEAP LEACH FLOWSHEET



TWO-STAGE COUNTER-CURRENT FLOWSHEET

For enhancing leach solution concentration



TWO-STAGE COUNTER-CURRENT FLOWSHEET (CONT.)

- PLS stage (primary) leaches fresh ore to achieve the target concentration in the PLS - operates on the first portion of the leach curve where leach kinetics are fastest.
- ILS stage (secondary) is scavenges leached ore, and operates on the final portion of the leach curve where the leach kinetics have slowed down. Rest-rinse operation is sometimes used during secondary.

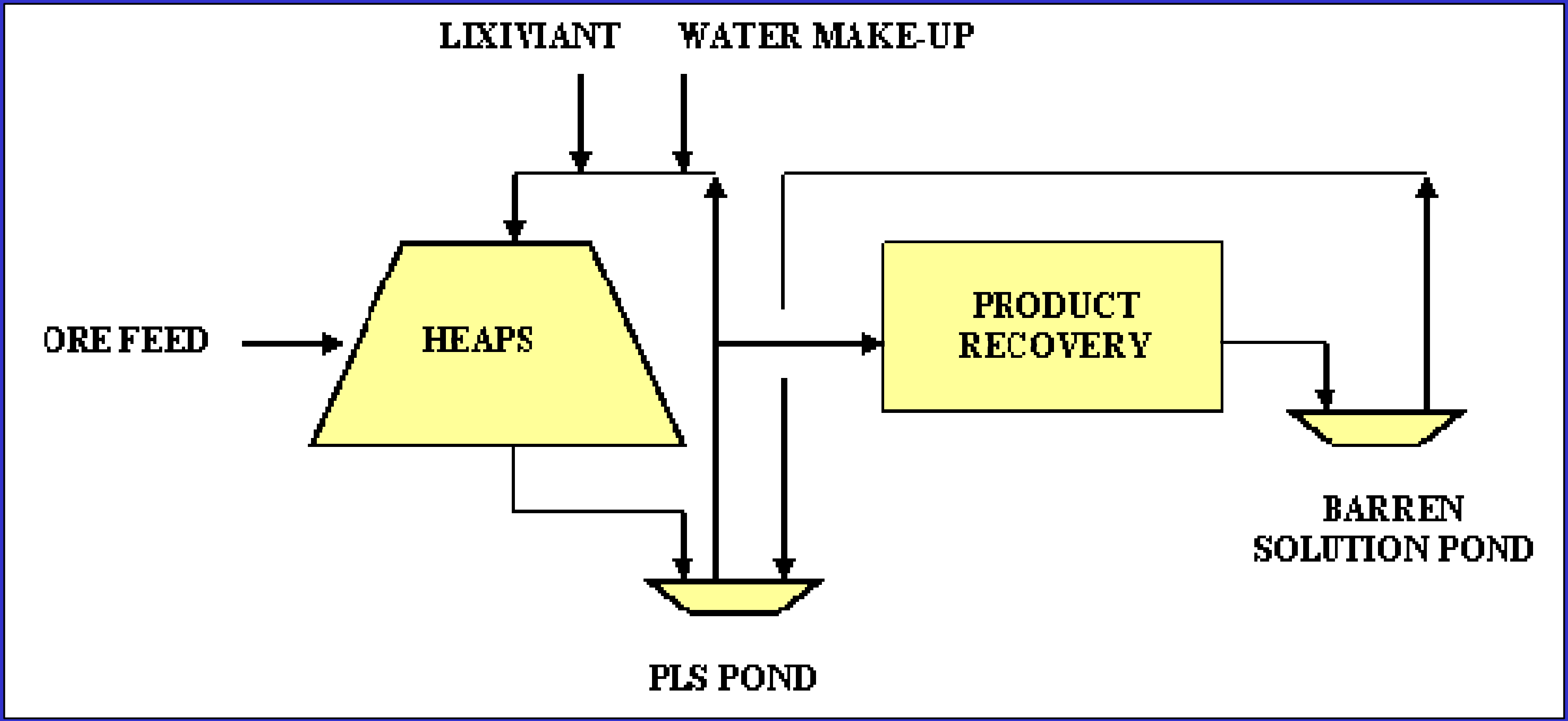
TWO-STAGE COUNTER-CURRENT FLOWSHEET (CONT.)

Disadvantages include:

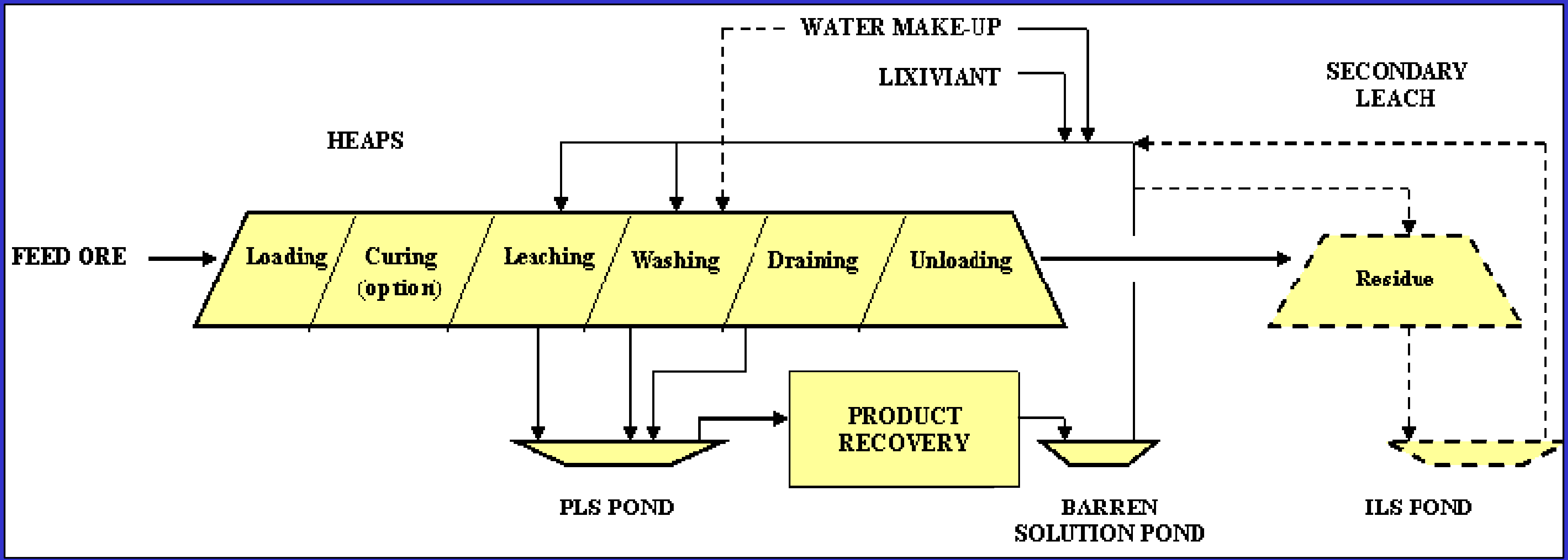
- Larger area under leach which can increase the evaporation loss.
- Larger catchment for rain (or snow) which can increase dilution of the leach solution.
- Increased heat loss, which can be a disadvantage in cold climates.
- Increased operating cost if aeration is included.
- Increased capital cost due to the additional pond, pumps and piping.
- May require a large area of leach pad.

PLS RECIRCULATION FLOWSHEET

Alternative arangement for enhancing solution concentration



ON-OFF (OR DYNAMIC) PAD FLOWSHEET



ON-OFF PAD (CONT.)

Advantages include:

- Favored when available space is inadequate for permanent heaps.
- Suitable when ore characteristics limit heap to single lift
- Facilitates placing residue in mined out pits.

Disadvantages include:

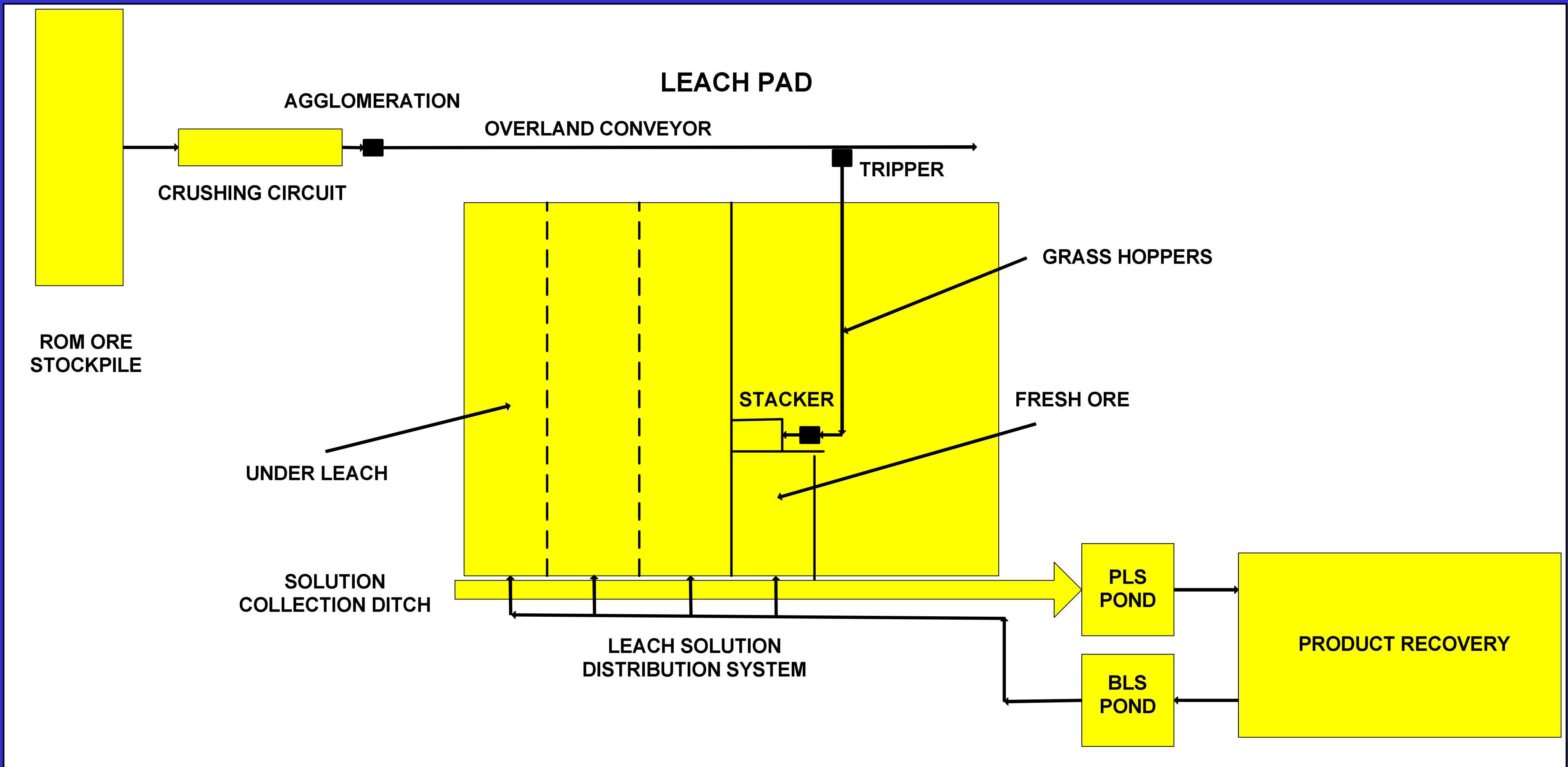
- Rehandling of leach residue adds to operating cost.
- Finite pad area represents a significant risk in scale-up.
- May require secondary permanent pad leach to maximize recovery.

HEAP LEACH PLANT LAYOUT

Factors affecting layout include:

- Availability of suitable area.
- Size of operation.
- Site topography and drainage patterns.
- Nature of terrain.
- Climate.
- Type of heap leach operation: permanent pads or on-off pads, crushed or ROM ore.
- Type of downstream process, SX or IX.

TYPICAL PERMANENT PAD HEAP LEACH LAYOUT



(BLS = Barren Leach Solution)

ORE TRANSPORT & HEAP BUILDING METHODS

- Ore transport: trucks or conveyor system (generally including portable “grasshoppers”).
- Heap building methods: trucks, radial stacker, mobile stacking conveyor system, front-end loader, excavator.
- Low ground pressure dozer can be used for heap top surface levelling.

HEAP BUILDING METHOD SELECTION

Factors include:

- System type: permanent or on-off.
- Particle size – ROM, coarse crush, fine crush.
- Ore characteristics – fines content, competence, clays, moisture content.
- Avoidance of segregation of coarse and fines which causes channelling.
- Careful handling of agglomerates to avoid breakdown.
- Ore transport distances.
- Number and height of lifts.
- Flexibility needed for limited or irregular heap surface area.
- Climatic conditions.
- Relative capital and operating costs.
- Ore throughput.

PROCESS CONTROL STRATEGY

- All important – can “make or break” project.
- Must be joint mining-leaching strategy. No room for “we and they” thinking.
- Metallurgical test data used to develop initial control model must be updated as real data becomes available.
- Must allow for “flywheel effect” – response to process changes slow, especially for multiple lifts.
- Always have at least one panel of fresh ore available to to supply high grade solution to maintain PLS grade.

TESTWORK PROGRAM OUTLINE

- Initial ore characterization – chemical analysis, mineralogy.
- Ore sorting amenability tests if appropriate.
- Bottle roll leach tests (for acid and alkaline leaching if appropriate).
- Short column leach test program (for acid and alkaline leaching if appropriate).
- Downstream process testwork –IX or SX.
- Tall column test program in closed circuit with IX or SX
- Pilot scale test heaps or large diameter columns as required.

TESTWORK PROGRAM ISSUES

- Lengthy program duration, especially for sulphides.
- Large quantities of drill core required.
- If ore sorting included, samples for column tests and test heap must be sorted.
- If sulphide ore included, testwork will involve bioleach conditions such as bacteria inoculation and aeration.
- Health and safety procedures and monitoring needed.
- Regulations for transport of samples and return of residues could affect location of testing lab.
- Field test heap program will require appropriate permits and plan for decommissioning.
- Safety factors <u>must</u> be applied to test data for scale-up.

CURRENT PROJECTS

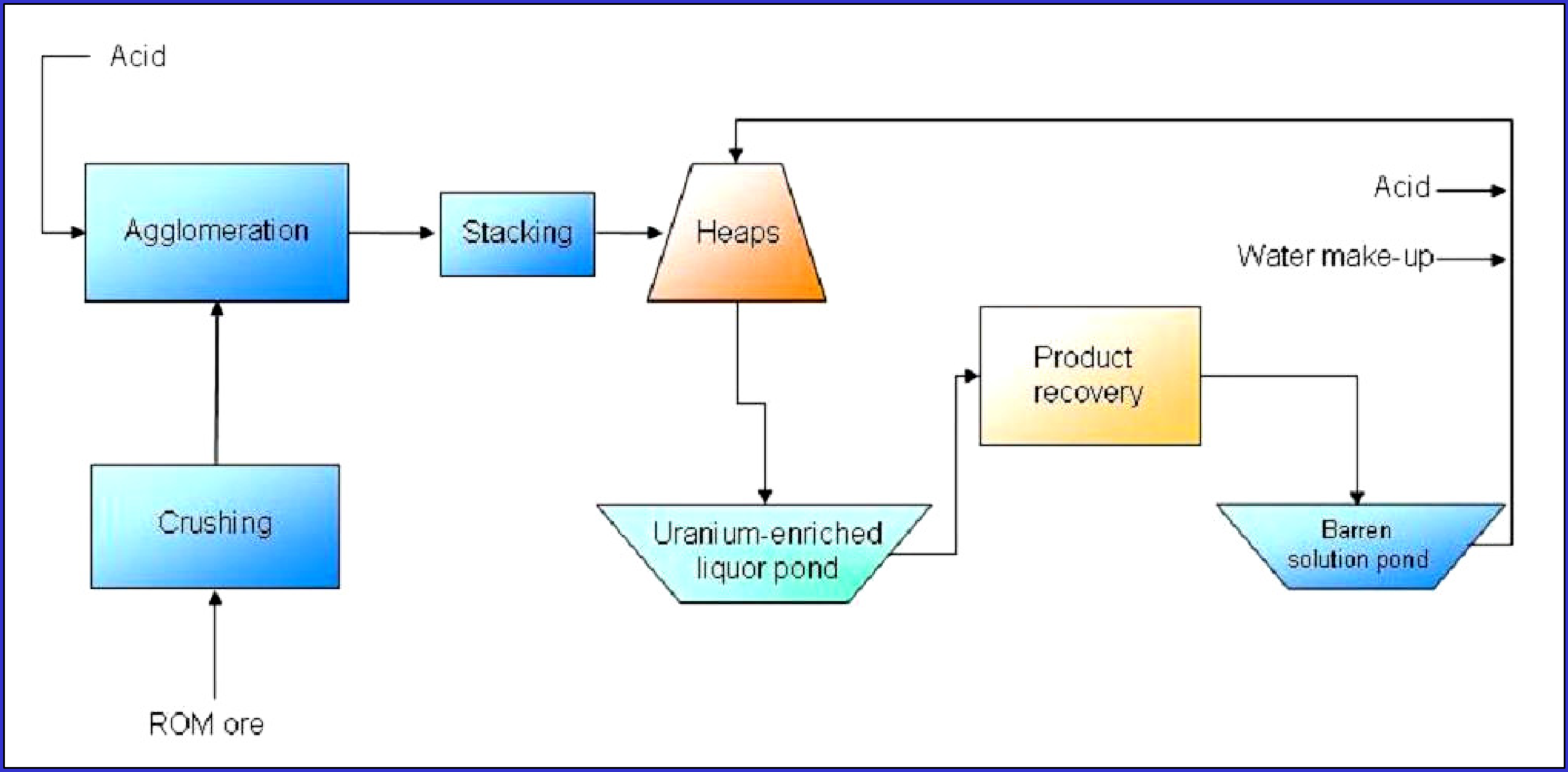
HL Projects at existing operations (acid leach) include:

- Ranger, NT, Australia, ERA
- Rossing, Namibia, Rio Tinto Group.
- Arlit, Niger, Areva Group

New projects (alkaline leach) include:

- Trekopje, Namibia, Areva
- Letlhakane, Botswana, A-CAP

PROPOSED RANGER FLOWSHEET
Ref: DEWHA Web Site



PROPOSED RANGER FLOWSHEET (CONT.)
Ref: DEWHA Web Site

- Acid leach system with agglomeration.
- Single lift ~5m high, on-off pad.
- Residue to be placed in temporary storage for later placement in pit.

TREKOPJE PROJECT

- Large low grade carnotite deposit, 0.013-0.014% U_3O_8.
- Claimed to be world’s first commercial alkaline heap leach.
- Trial mine in 2008.
- Start-up projected for 2009/2010, full production in 2011.
- Projected production 3,500 t/a U.

TREKOPJE PROJECT (CONT.)

- On-off leach pad system.
- Recovery by IX using NIMCIX column design.
- Leached ore to be deposited the shallow in mined out areas for environmental reasons. (Project is located in a national park area.)
- Carnotite mineralization is hexavalent - oxidant not needed.

FUTURE TRENDS

Heap leaching is likely to be increasingly favoured due to:

- Available ores tend to be lower grade.
- Low capex and opex.
- Extensive industry experience with heap leaching of gold and copper ores.
- Suitability for small deposits.
- Relatively inexpensive way to increase production from existing operations.